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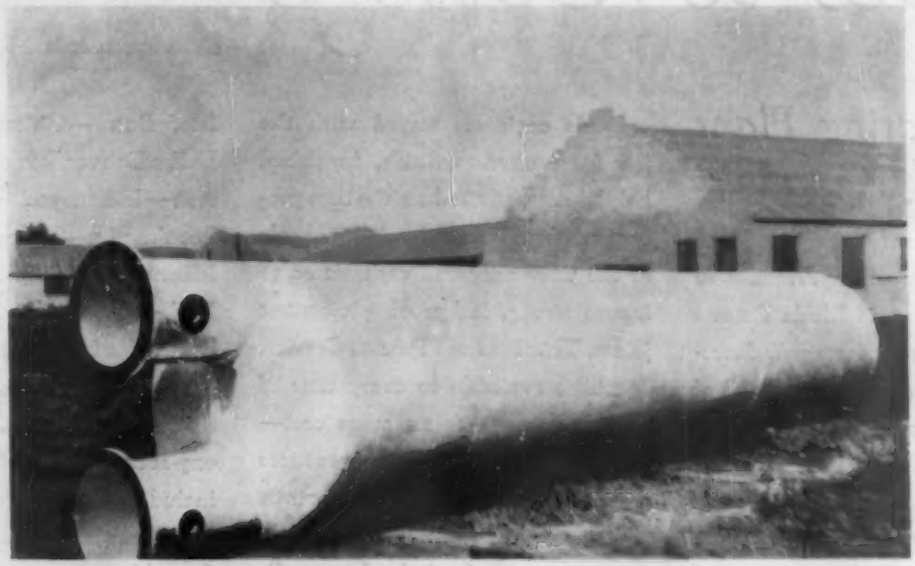

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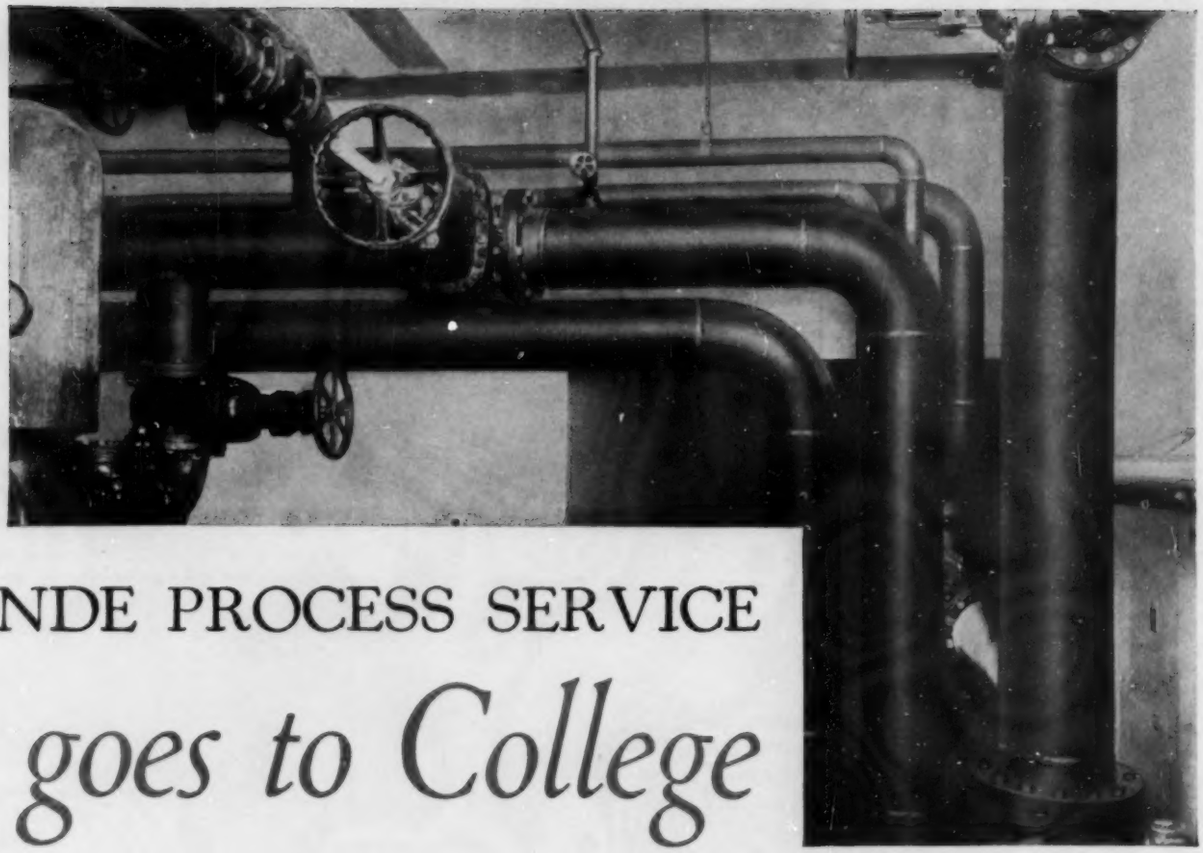
PUBLISHED MONTHLY FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING



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THE
AMERICAN WELDING SOCIETY
JOURNAL

WM. SPRARAGEN, Editor | VOL. 13 | NO. 12

DECEMBER

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Automatic A.C. Arc Welding of Class I Pressure Vessels*

By O. A. TILTON†

IN THE field of electric arc welding, development has been so rapid in the past ten years that we are accustomed to consider practices which have been in effect from two to four years, as old and established customs. It may, therefore, be stated that automatic welding of Class I pressure vessels with A.C. is not new. However, this thought should be qualified by the statement that it is only quite recently that the automatic equipment, transformers, electrodes and procedure have become generally available for industry through the developmental effort of concerns which are in the field of commercial exploitation of welding.

A.C. welding, in itself, has been known and practiced fully as long as D.C. welding but its application has been very limited. The reason for this is that until heavily coated electrodes were generally available and the welding of unfired pressure vessels was officially sanctioned by the A. S. M. E. Code, the field in which A.C. shows up to best advantage was practically nonexistent. It is probably correct to say also that an unfortunate prejudice against A.C. was established in American engineering circles in those earlier days of welding, which no doubt lengthened the time until its proper application became recognized as it is today.

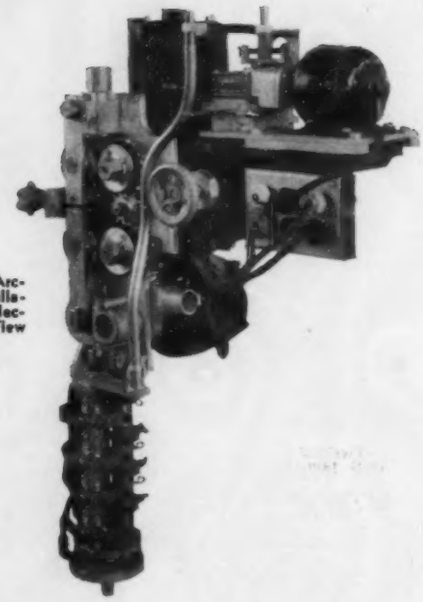

Fig. 2—Automatic Arc-Welding Head with Oscillator for Heavily Coated Electrodes. Right Front View

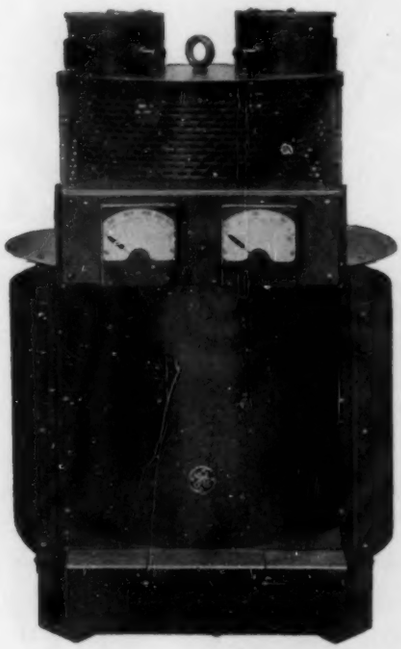

Fig. 1.—Alternating-Current Arc-Welding Set Combined High Reactance Transformer with Tapped Reactor and Instruments, 60 Cycles, 750 Amp.

Metallurgically and physically it appears that a prerequisite to Class I welding is the use of heavily coated electrodes, sometimes known as the shielded arc type. This latter term appears to have originated with the gaseous shielded arc developments of Dr. P. P. Alexander and Prof. Elihu Thomson of the General Electric Research Laboratories in 1924, described in the March 1926 issue of the *G.E. Review*. Shielded arc electrodes form a gaseous envelope around the arc, excluding the detrimental elements, oxygen and nitrogen, of the atmosphere from contact with the molten metal as it passes through the arc. They also deposit a slag coating on top of the weld metal, further protecting it during solidification, as well as contributing somewhat of a grain refining function. In some cases the heavy coating of the rod includes alloying elements. With shielded arc electrodes it is possible to obtain deposited weld metal equal, and often superior, in many of its properties to rolled plate parent stock.

Controlled welding of the sort just mentioned eliminates many of the uncertainties inherent in bare-wire welding which in that case became excessively troublesome when welding currents much in excess of 250 amperes were used. With these factors removed, it was natural to go to higher welding currents with their increased electrode melting rates and at the same time obtain required penetration due to the concentration of heat by the electrode coatings.

For some time excellent work has been done with

* Paper presented at Fall Meeting, A. W. S., in New York, October 1–5, 1934.

† Industrial Engineering Dept., General Electric Co.

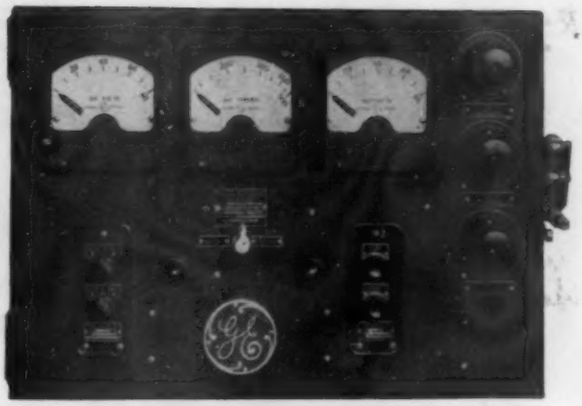

Fig. 3—Automatic Arc-Welding Instrument Panel for Use with Welding Head for Heavily Coated Electrodes. Front View

shielded arc electrodes and D.C. but there still remained a troublesome factor, magnetic blow, the effects of which were to slow down production rates and increase unit costs. Although it is possible to largely counteract the effects of magnetic blow by a proper arrangement of D.C. solenoid magnets, it has appeared impossible to do anything about magnetic blow by changes in electrode characteristics. Since the use of A.C. would naturally largely avoid this trouble, it remained for the metallurgists to develop electrodes which would operate satisfactorily with A.C.

It is seen, therefore, that electrode development is largely responsible for making practical the use of A.C. in the heavy current field of pressure vessel welding. There appears to be but one advantage, the practical elimination of magnetic blow, to be gained by using A.C. for welding, but that is a very important one from the standpoint of increased speed, more uniformly high quality results and reduced unit costs.

There seems to be an inherent characteristic of the A.C. arc which requires certain closely defined electrode characteristics. It has therefore been found that electrodes formerly satisfactory for D.C. are not necessarily successful with A.C. However, it is now known that properly designed A.C. electrodes are likewise good when used with D.C.

In order that our story should be complete, we must not omit stating the disadvantages of A.C., but at the same time experience has shown that elimination of magnetic blow is, in many cases, of so great importance as to outweigh these disadvantages. They are:

1. It is impractical to use bare or lightly coated electrodes with A.C. because with them it is difficult if not impossible to make as good a weld as with D.C.
2. A.C. welding is now only practicable with single phase and inherently involves either low power factor or low efficiency. The two former, generally considered undesirable load characteristics by power companies, sometimes involve excessive penalties unless power factor and phase distribution corrective equipment is also installed.
3. The first cost of A.C. equipment is no lower and may be higher than D.C. when corrective equipment is required.
4. There is a psychological element involved in the use of A.C. which is probably inherited from the earlier days when A.C. equipment was less reasonably designed. This is a fear of shock on the part of welding operators. We call this psychological because it is actually unjustifiable since present-day application of A.C. tends toward the use of such low values of secondary voltages as to make the danger practically nonexistent. Voltage-reducing auxiliary attachments eliminate this objection but, of course, add certain costs which are a necessary evil, we hope of a temporary nature only.

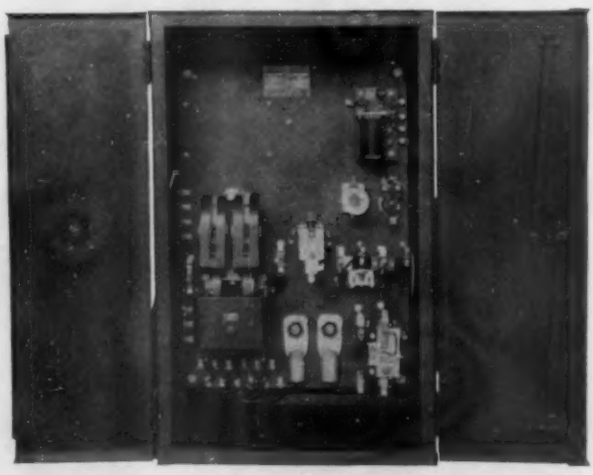

Fig. 4—Automatic Arc-Welding Travel Carriage. End View Showing Welding Control with Doors Open

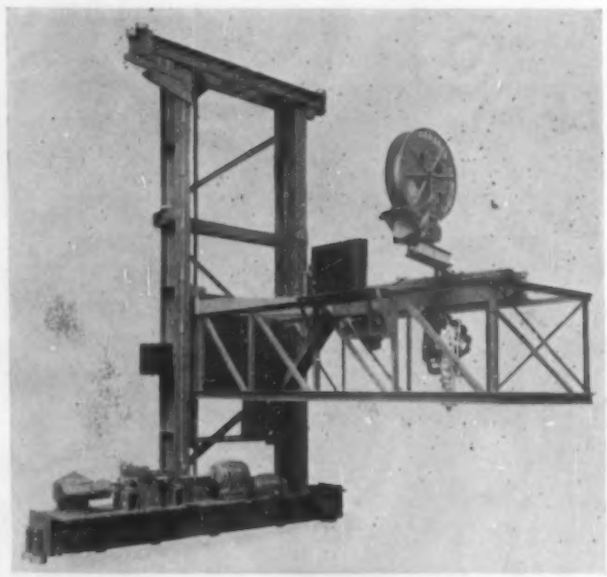

Fig. 5—Automatic Arc-Welding Machine for Welding Heavy-Walled Pipe 4 Ft. to 14 Ft. in Diam.

In the field of welding covered by my subject, there is available a complete line of equipment for A.C. A typical installation will be described later. Transformer Welding Units as shown in Fig. 1 are offered by G.E. in the following sizes:

Amp. Ratings (85 Deg. C.) 1 Hour	Continuous	Terminal Volts Operation	Open Cir.	Current Range Max.	Min.
500	375	40	80/90/100	500	125
750	575	40	"	750	175
1000	750	40	"	1000	250

Primary: Single phase, 60, 50 or 25 cycles; 220, 440 or 550 volts. Auxiliary attachments are:

1. An extra attachment for reducing secondary open-circuit voltage to 50% of normal.
2. An extra attachment for low currents down to 10% of the one hour rating.

A welding transformer unit is essentially a high reactance transformer with a means of adjusting reactance for purpose of current adjustment. The reactance is for the purpose of reducing the secondary voltage from the striking or no-load voltage down to that required for the arc. These values are at present approximately 80 volts and may even be as low as 65 volts at no load, to 40 volts at the arc. Besides the switches or other means of current control, each unit has a voltmeter and an ammeter and enclosed primary and secondary terminal lugs. Due to the service for which they are intended, these units are necessarily of the air-cooled type and for stationary mounting. Voltage and current reducing attachments when used are mounted on the transformers with suitable enclosures.

An automatic arc-welding head, to justify its name as such, is a motor-driven, wire-feeding device, with electrical control which causes automatic maintenance of the arc length irrespective of variations in electrode melting rate. Such devices also are provided with means of conducting the welding current to the metallic electrode at a point which remains at a constant distance

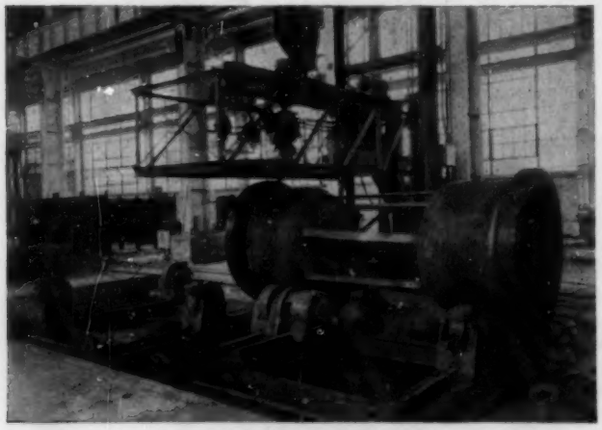

Fig. 6—Set-Up for Automatic Welding

from the arc at all times. It is always preferable in automatic welding to use electrode in continuous lengths from a reel. Unless this is done, one of the important economies of this process is lost, namely, the saving of the loss of electrode material in short ends that cannot be consumed. With the proper combination of a well-designed electrode and automatic head, no difficulty is encountered in feeding any size and type of shielded arc electrode which can be reeled without destroying its coating.

An automatic arc-welding head with its control and instrument panels is shown in Figs. 2, 3 and 4. This machine is adaptable for welding with either A.C. or D.C., by the proper combination of its control elements. The features of this device are briefly as follows:

1. The heavily coated electrode is fed from a reel in a continuous length.
2. A high-speed milling cutter, tipped with Carboloy, slits the coating of the electrode just after it passes through the feed rolls.
3. Brushes conduct the welding current to the bared-steel base wire, through the slot in the coating and at a uniform distance from the arc.

Other points of interest are the oscillating attachment by which adjustment of the amplitude, frequency and direction of oscillation of the arc may be obtained. The

Fig. 7—Interior View of Welding Shop of the Foster Wheeler Corp.

speed of electrode feed may be increased or decreased by a simple gear shifting device, without stopping the machine.

All electrical adjustments are made from the instrument panel which may be located at any convenient point. In this panel are mounted instruments for reading welding current and voltage, switches for starting, stopping and reversing the wire feed and a rheostat for adjusting the speed of wire feed. There are also provisions for other control items when used, such as a rheostat for adjusting travel carriage speed and switches for independently controlling this function.

Suitable electrodes for automatic A.C. welding of Class I Pressure Vessels have, beside the necessary arcing characteristics, a high gas producing coating and one which provides complete slag coverage for the weld. The slag is easily removed from the weld metal after it has cooled. It is, of course, understood that the resultant weld deposit meets the physical and X-ray requirements for Class 1 pressure vessels with the minimum expenditure of effort and time.

For use with this automatic arc-welding machine, heavily coated shielded arc electrode is provided in several varieties, as required by the material and process involved. It is covered by a fabric coating heavily impregnated with fluxing ingredients. This securely ad-

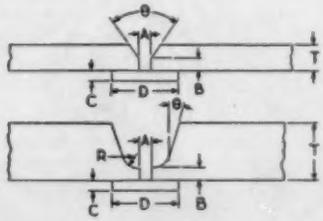

Fig. 8

Fig. 9

Fig 10

Plate Thickness T Inches	Edge Preparation Fig No.	θ Degrees	A Inches	B Inches	C Inches	D Inches	R Inches	Number of Passes
1/4	8	70	1/8-5/32	1/8	1/8	1 1/4	—	3
3/8	8	70	1/8-5/32	1/8	1/8	1 1/4	—	4
1/2	8	70	1/8-5/32	1/8	1/8	1 1/4	—	6
5/8	9	70	1/8-5/32	1/8	1/8	1 1/4	—	7
3/4	9	7 to 9	1/8-5/32	1/8	1/8	1 1/4	5/16	8
7/8	9	7 to 9	1/8-5/32	1/8	1/8	1 1/4	5/16	9
1	9	7 to 9	1/8-5/32	1/8	1/8	1 1/4	5/16	12
1 1/8	9	7 to 9	1/8-5/32	1/8	1/8	1 1/4	5/16	13
1 1/4	9	7 to 9	1/8-5/32	1/8	1/8	1 1/4	5/16	15
1 3/8	9	7 to 9	1/8-5/32	1/8	1/8	1 1/4	5/16	16
1 1/2	9	7 to 9	1/8-5/32	1/8	1/8	1 1/4	5/16	16

Fig. 11
Typical Welding Data

Plate Thickness Inches	Description of Passes	Pass No.	Electrode Diameter Inches	Welding Current Amp.	Arc Voltage	Approx. Welding Speed Inches per Minute	Electrode Consumption Pounds per Minute	Oscillation	
								Approx. Amplitude Inches	Frequency Osc./min.
$\frac{1}{2}$"	Bottom of Groove	1	5/32	130	25	7½ to 8	.045	None	
		2	3/16	175	28	6	.074	None	
		3	3/16	175	28	5	.074	1/32	
		4	1/4	275	30	4¾	.13	1/16	
	Hand Backing Beads	5	1/4	275	30	4½	.13	1/16	
		6	1/4	275	30	4¼	.13	3/32	
1$\frac{1}{2}$"	Bottom of Groove	1	3/16	175	28	7½ to 8	.074	None	
		2	3/16	175	28	6	.074	None	
		3	1/4	380	38	5	.20	1/32	36
		4	1/4	380	38	4¾	.20	1/16	36
		5	1/4	380	38	4½	.20	3/32	36
		6	1/4	380	38	4¼	.20	1/8	36
		7	1/4	380	38	4	.20	5/32	36
		8	1/4	380	38	3½	.20	3/16	36
		9	1/4	380	38	3½	.20	7/32	36
		10	1/4	380	38	3½	.20	1/4	36
		11	1/4	380	38	3¼	.20	9/32	36
		12	1/4	380	38	3¼	.20	5/16	36
		13	1/4	380	38	3	.20	11/32	36
	Hand Backing Beads	14	1/4	380	38	3	.20	1/16	
		15	1/4	380	38	3	.20	3/32	
		16	1/4	320	38	3	.16	1/8	

heres to the base wire, due to the properties of the ingredients used. A colored spiral tracer thread is used to still further prevent damage to the coating in handling, as well as a means of identifying the various types of rod.

To apply the process and equipment I have described to Class I pressure vessels requires certain fixtures for holding the work in position and for traversing the arc across the work or *vice versa*, as well as material handling devices. These vary with the plant layout and are generally built to the particular specifications accompanying each individual installation. They are, however, all based on the well-known principles of rolling devices for circumferential seams and travel carriages for longitudinal seams.

Figures 5 and 6 show the elements that I have described and Fig. 6 shows their application to a typical installation.

One company now manufactures weld fabricated pressure vessels under the A.S.M.E. Code for Class I unfired pressure vessels. A.C. automatic arc welding is used exclusively for all seams excepting tank fittings, which are applied by hand welding with A.C. This installation has been in successful production operation since the latter part of May 1934 and has turned out approximately 225 tons of Class I vessels, up to September 1, 1934.

Fig. 12—Typical Shell Showing Test Plate Attached and Markings for X-Ray

Fig. 13—X-Ray Equipment

This concern has been actively engaged in weld fabrication for several years, but it is only recently that they equipped themselves for Class I pressure vessel welding. The data given at this time is not intended as an impressive display of quantity production but is of particular interest as an example of high quality welding with A.C. successfully applied.

Figure 7 shows a general view of the interior of the welding shop from the west end. The shop is approximately 400 ft. by 75 ft. and equipped with seven bridge cranes for material handling. Three-phase, sixty-cycle primary power is purchased from the Power Company, at 26,400 volts. A bank of 6 150 kv-a. transformers

step this down for the 220-volt, 3-phase, 60-cycle shop supply. Direct current for variable speed drives, such as the automatic welding machine, the travel carriage motors and the rolling device drives, can be furnished from a 220-kw., 275-volt D.C. generator, driven by a 260-hp. synchronous motor. It is interesting to note that this welding shop is another instance of a foundry which has been converted into a weld fabricating shop, notwithstanding the fact that it was the most modern and one of the largest foundries in the Metropolitan District when placed in operation in April 1924. This is a splendid example of modernization.

It should be stated at this time that certain elements of the shop equipment have not as yet been placed in their final position. However, as this layout is already planned, our description will make the temporary assumption that all equipment is installed in its intended location.

Most of the plate stock is purchased from the mill as required. This is common practice for such work. However, a small stock of light-gage plates is kept on hand at present in outdoor storage.

Often it is found desirable to have the plate edges machined at the mill, to the specified groove. All other

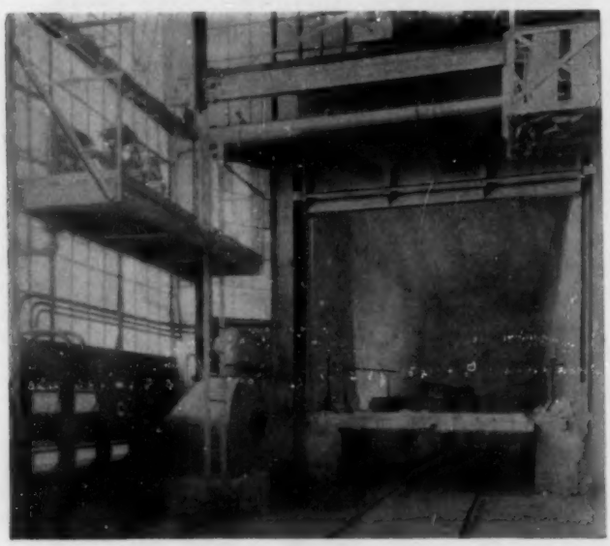

Fig. 14—Annealing Furnace

stock can be planed on a standard type plate planer, 38 ft. long which will handle at least 4 in. thickness without difficulty.

Shells from 33 in. minimum diam. up to the largest which can be shipped, 14 ft. diam., can be rolled on the 200-ton rolling equipment. An hydraulic pressure-break takes care of the preliminary breaking of the plate edges.

The east end of the building is given over to these preliminary operations. Hand welding stations are located at convenient points in this section, for tack welding. Tack welding is done with $^{3}/_{16}$ in. diam. electrode, using A.C. and approximately 150 amperes and 23 volts.

The shells are then taken to the automatic welding machine, located in the center of the building. This consists of the travel carriage assembly shown in Fig. 5, mounted on upper and lower supporting rails, with a length of travel of 70 ft. Alongside this track is a pit 65 ft. in length, approximately 12 ft. wide and 3 ft. deep

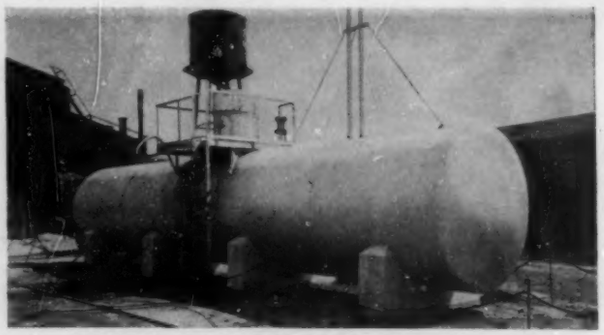

Fig. 15—Butane Storage Tank

in which are four units for holding the vessels. Two of these and a portion of the pit are shown in Fig. 6. Each alternate unit consists of a motor-driven rolling device and the other units are idling rollers. The motor-driven units are synchronized by control. For longitudinal seams the rolls remain stationary and the travel carriage moves along the seam, whereas for circumferential seams the travel carriage remains stationary and the shells are rolled under the arc. Each device is adjustable as to speed, from 2 to 15 in. per minute. Vessels from 2 ft. to 14 ft. diam. and up to 70 ft. long can be handled on this equipment.

The welding procedure is as follows:

The bevel or groove is shown in Fig. 8 for plate thicknesses up to and including $^{1}/_{2}$ in. and in Fig. 9 for all heavier plates. Experience has proved that the angle of V-bevel and of the sides of the U-groove are an important factor in obtaining successful results. Wider angles add nothing to quality and increase costs by requiring more weld metal deposit, which also reduces net welding speeds. Narrower angles tend to produce undercutting of the bottom layers of weld metal, thus entrapping slag and increasing the effort required in cleaning between passes and in repairing defects detected by the X-ray.

The first welding operation is the longitudinal seam. The tabulation in Fig. 10 gives the plate thickness, type of bevel (U or V) and its dimensions and the number of layers or passes. Figure 11 gives typical welding data and includes the electrode type and diameter per pass, the corresponding welding current, arc voltage, welding speed, wire consumption and oscillation amplitude and frequency. This data applies also to circumferential seams and is irrespective of vessel diameter or length.

The order of procedure is to weld the groove full, including reinforcement at the top, then chip off the backing-up strip and reweld the back of the groove by hand, filling in the weld metal that was removed in chipping

Fig. 16—Fittings Are Hand Welded

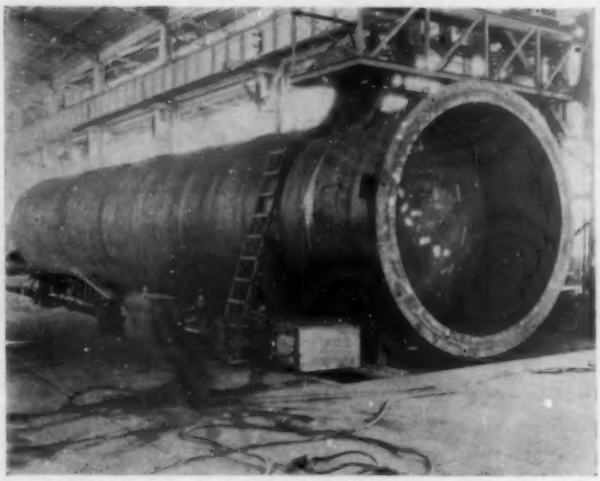

Fig. 17—A.C. Welding of Large Fractionating Tower for Petroleum Refining

off the backing-up strip, and reinforcing the weld on the back. Welding layers average 1/8 in. thickness and reinforcement extends above the plate surface the amount required by the boiler code. This reinforcement is chipped off on all fired pressure vessels or when the customer requires it to be done on other vessels.

Cleaning between passes is accomplished by loosening the slag with a hooked instrument much like a pinchbar. The chips are blown out and the oxides and spatter are removed from the sides of the groove with a pneumatic tool. The weld is then cleaned again with a hand wire brush.

The welding transformer for the automatic is rated 750 amps. 1 hour or 575 amps. continuous, 40 volts secondary. Five hundred ampere transformers are used for hand welding. No power-factor correction is applied as other plant equipment provides sufficient corrective kv-a. in synchronous motor drive. Phase balancing is sufficiently well taken care of by distribution of the single-phase units on the 3-phase system.

After welding, the test plates are removed and all seams are marked with the usual lead identification markers, for X-ray examination. Figure 12 shows a typical shell, before removal of the test plates and with markings for X-ray examination. Every seam is examined with an X-ray machine equipped with a 300-000-volt tube. Figure 13 shows the X-ray machine in position for examining the circumferential seam of a vessel. This machine is of the most modern type known and is mounted on a special truck for ready portability. Defects when found are chipped out, rewelded and X-rayed again. Permanent record is kept of every inch of welded seam. To date, this company has automatically welded and X-rayed 1400 lin. ft. of welded seams and has found 0.04% of defects, which have been completely eliminated before completion of the vessels. This remarkable record is particularly notable when it is known that the defective welds are considered to have all been due to imperfect plate edge preparation. This company states that when they have eliminated the defective grooving they expect to practically eliminate the small number of weld defects that are now being encountered.

The test plates are the first to be X-rayed. They are then removed and while the vessel itself is being examined these samples are stress-relieved in a small electric furnace under exactly the same conditions that will be applied to the entire vessel. These conditions are accurately controlled and recorded for duplication on the vessel. Physical tests are then made and the check tests of the seam are completed nearly as soon as the vessel is ready for the furnace. No case has yet been found where the physical tests fail to meet all the Code requirements.

The following average physical properties after stress-relieving at 1200° F. have been obtained on A. S. M. E. S-1 Boiler Plate:

Ultimate tensile strength	65,000 lb. per sq. in.
Yield point	54,000 lb. per sq. in.
Elongation, 0.505 specimen	31% in 2 in.
Elongation, free-bend	52%
Specific gravity	7.825
Impact (Charpy)	33 ft.-lb.

After X-ray, the complete shell is placed in the butane gas-fired furnace shown in Fig. 14 which will accommodate vessels up to 14 ft. diam. and 30 ft. long. The butane storage tank shown in Fig. 15 is located outside the southwest end of the building. This tank is a Class 2 vessel, also welded with the equipment and process described. The furnace is located at the northwest end and just outside the welding shop. Strain-relief annealing consists of heating to 1200° F. and maintaining this temperature for 1 hour per inch of maximum plate thickness, then cooling to 500° F. in the furnace. The rate of increase and decrease in temperature is three hours to raise from room temperature to 1200° F. and 5 hours to cool to 500° F.

Fig. 18—Welded Vessel Ready for Shipment

Hand welding of fittings is also done with A.C. The work is positioned for this operation. Figure 16 shows typical vessel with the hand-welded fittings being attached.

Automatic welding has proved so satisfactory that in every case in which it is possible to do so, hand welding has been eliminated. Figure 6 shows the adaptation of two heavy-flanged heads for the automatic. These four circumferential seams formerly were hand welded due to the difficulty of mounting on the automatic. They are now temporarily welded together in order to permit the greater economy and uniformly high quality obtainable from automatic welding.

Figure 17 shows the welding of a large fractionating tower for petroleum refining.

Figure 18 shows a vessel welded with the equipment and process described and ready for shipment. It is interesting to note that in the background may be seen what is said to be the largest horizontal boring mill in the world.

Experience of this particular pressure vessel manufacturer is that the A.C. automatic gives them somewhat greater net welding speeds than could be obtained with D.C., and fewer defects to be chipped out. On hand welding, except with low-current values, the operators like the A.C. arc to handle. These same men were originally trained on D.C. and, without exception, express preference for A.C. because of the ease with which it may be handled.

Resistance Welding of Thin-Gage Duralumin*

By N. F. WARD, M.M.E.†

Introductory

WITH the advent of the "all-metal" airplane, the utilization of metal in thin-gage strips and sheets has been intensified. The high standards of quality, which are demanded for units fabricated of metal in the airplane industry, have established riveting as axiomatic for all structural parts of the modern all-metal airplane. For want of a better method, riveted joints predominate except for fusion-welded tanks, and fittings or minor fastenings which are joined by resistance welding.

Resistance welding as a fabrication tool for thin-gage metal structures has received, except in a few isolated instances of airplane structural application, less of an intensified study than has been devoted to riveted joints. Recognition has been made of the possibilities for effecting economies in fabrication and speed of assembly, which are inherent in the simplicity of design for the resistance welding process.†† The major difficulty encountered depends upon the electromechanical details of the process.

When a high quality of weld metal is to be controlled, accuracy of welding time, electrode pressure and power impulse are essential, and uniformity of quality in a joint welded by the resistance method results. The loss of strength for duralumin, which is the metal under discussion, is conditioned by these factors. In any event accurate evaluation is possible, whereas for the riveted joint many details are doubtful, especially the rivet hole and rivet shank relationship except when determined by X-ray. In other words, the resistance welded joint in its inherent refinement can be designed for accurate limits of loading when scientific control is maintained.

Fig. 1—Layout of Welder Timer and Breaker Circuits for Spot Welding. Water Tank for Submerged Welding Is Shown in Place on the Welding Electrodes

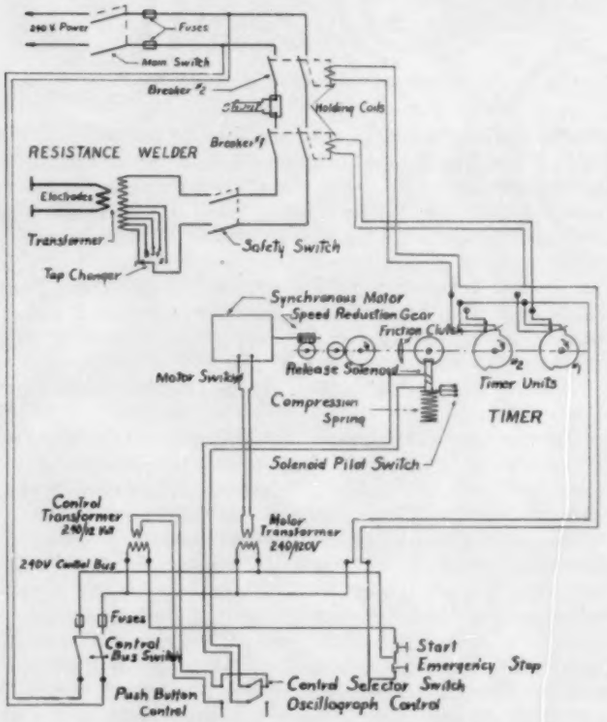

Fig. 2—Wiring Diagram for Spot Welding Experiments

The purpose of this preliminary investigation is to study the elements which influence the quality of duralumin, commonly called 17ST, when welded by the resistance method. For purposes of this study the most widely used thickness has been selected. This thickness was 0.018 in. and used in the condition as received in the rolled sheet.

The light gages of duralumin were representative of the most widely used thicknesses in wing covering and control surfaces. Data for the 0.018 in. thickness have not been available in published form, and data were obtained for the other gages which could be welded on the equipment as installed.

Factors Affecting Quality of Welds

A brief analysis shows that many variables of the process are involved which affect the physical and metallurgical properties of the spot welds. The accuracy with which these factors are controlled determines, in a large degree, the success or failure of the spot weld. The important considerations are outlined here.

1. *Heat Generated for Given Current and Resistance of*

* Paper presented at Fall Meeting, A. W. S., Oct. 1–5, 1934, in New York. Contribution to Fundamental Research Committee, A. B. W.

† Assistant Professor of Mechanical Engineering at University of California.

†† See bibliography at end of paper.

Fig. 3

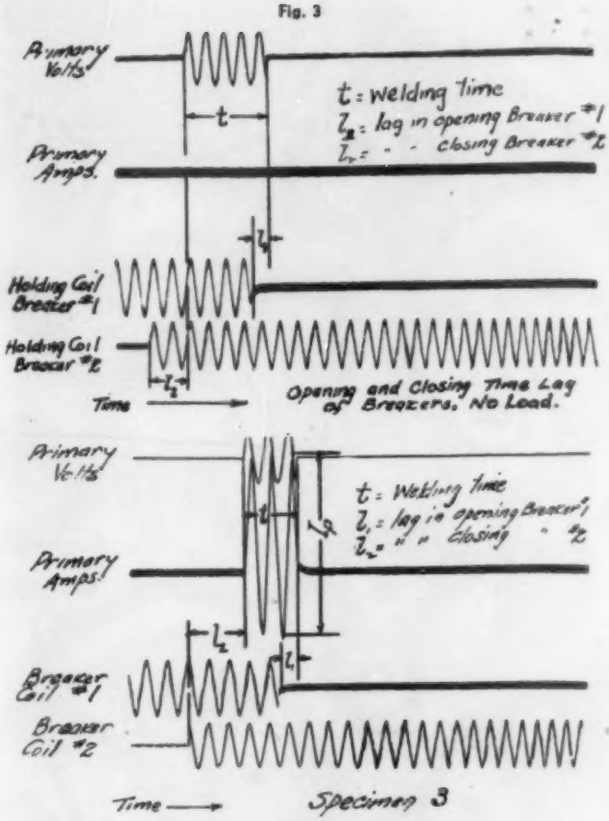

Fig. 4

Specimen Metal.—Energy must be available to produce fusion heats. Aluminum and its alloys, being excellent electrical conductors because of their low resistance, require high current density to insure fusion under pressure. Increase in external resistance, such as poor electrical contact of specimens which are welded, reduces the available current density for a given capacity of the welder. Condition and proximity of surfaces in contact at the welder electrodes materially affect the temperature obtainable. During all tests the surfaces of the specimen were cleaned with carbon tetrachloride and mating surfaces pressed into contact while in alignment jig by required electrode pressure before energizing the welder. Only by manipulation of time of power impulse and current taps can optimum results be obtained.

2. *Pressure at Electrodes.*—Aluminum alloys have little or no compressive strength at fusion temperatures. Electrode contact with the surfaces must be firmly established and kept cool at electrode tip in order to localize fusion between interfaces of the metal and prevent serious undercutting of the areas in contact with the electrodes. When the pressure is insufficient to maintain electrical contact, arcing may occur which either fuses the sheet to the electrodes or leaves a porous weld.

3. *Electrode Shape.*—Relatively small electrodes insure the required high current density with the least disturbance of the magnetic field. Yet their shape when of copper alone is difficult to maintain unless of hard composition, such as tungsten-copper. Cylindrically shaped lower electrode with flat top and an upper electrode tip which is slightly spherical produces welds without undercutting when electrode pressure is correctly adjusted. Tips which are refinished with a file leave their rough imprint on the specimen and increase aluminum pick-up by the electrode. Redressing with a fine sandpaper produces the best finish unless there is serious deformation. Then tips should be turned in the lathe and matched by suitable templet to insure duplicate electrode dimensions.

4. *Time Duration of Power Impulse.*—A prolonged power cycle produces a rapid deterioration in strength. Too short a power impulse, unless it is of high amperage, results in imperfect bond between metals at electrode tips. Accurate timing is essential for duplication of results.

5. *Condition of Metal to Be Welded as Affected by Temperature.*—Duralumin maintains surface without undercutting when current density is high, electrode contact cool, pressure moderate and time impulse is a minimum. Duralumin does not appear to age naturally after welding or regain the strength at the weld. Subsequent heat treatment for such a small area as a spot weld involves additional handling and cost. The logical time for conditioning weld structure is while the weld is being placed. Air or water chilling while the weld is in process shows some promise.

6. *Thickness of Metal.*—Very thin gages cool quickly and develop higher unit strengths for the same kind of joint (lap, butt with single-cover or double-cover plates). Special jigs are an essential part of equipment to insure alignment of adjacent parts. Elastic failure in misaligned parts intensifies the unit stress in the weld, which can least afford to be jeopardized. Heavy-gage metal localizes loads in the softer welds if allowed to weave in the structure. Double or triple rows of alternately spaced welds furnish necessary stiffness at the juncture of plates to intensify stress in multiple spot welds. Tests

Fig. 5—Photomicrograph of a Porous Spot Weld. Note Stratified Areas of Large Grain. Magnified 90 X

Fig. 5(a)—Enlarged View of Area Near Weld, Showing Fine Grain but Tendency toward Non-Uniformity. Magnified 670 X

show that the strength does not increase directly with the increase in number of spot welds.

7. *Length of Secondary Leads.*—Use of short leads reduces voltage drop to minimum value. In this experiment the secondary leads were of constant length.

Time-Current Control

The most vital unit, which eliminates the variation usually present with manual operation of the time interval, was used during the investigation and is drawn schematically in Fig. 2. This unit consists of a synchronous motor drive which is geared to main timing disc shaft so that any one of several rotative speeds may be obtained. In this investigation the timing disc shaft rotated at 4 r.p.m. The time cycle for welding is initiated when the release solenoid on the timer is energized and permits the disc to rotate. The time interval is predetermined by setting the timing discs relative to each other, an amount equal to the desired interval. These discs make or break suitable electrical contacts, which in turn energize or de-energize the holding coils on the two breakers as shown in Fig. 2. The exact time interval for each setting was determined by a standard six-element oscillograph in which only four elements were used. The electrical connections including the oscillograph control appear in Fig. 2.

This timer was arranged to control two holding coils on two magnetic circuit breakers. The use of two circuit breakers was necessary to obtain sufficiently short enough interval for spot welding duralumin without undue electrical disturbance in the welding circuit. The oscillogram of the welding control in operation appears in Fig. 3 for no load. From this oscillogram it is evident that the lag of breaker No. 1 is one cycle ($^1/_{60}$ sec.) and that of breaker No. 2 is two cycles ($^1/_{30}$ sec.) alternating current. With so many variables it is necessary, if meaningful results are to be obtained, to maintain constant thickness of specimen, similarity in condition of metal specimen and electrode shape. The electrode pressure, power and time of welding were varied in systematic order, with the view of accurately controlling the process.

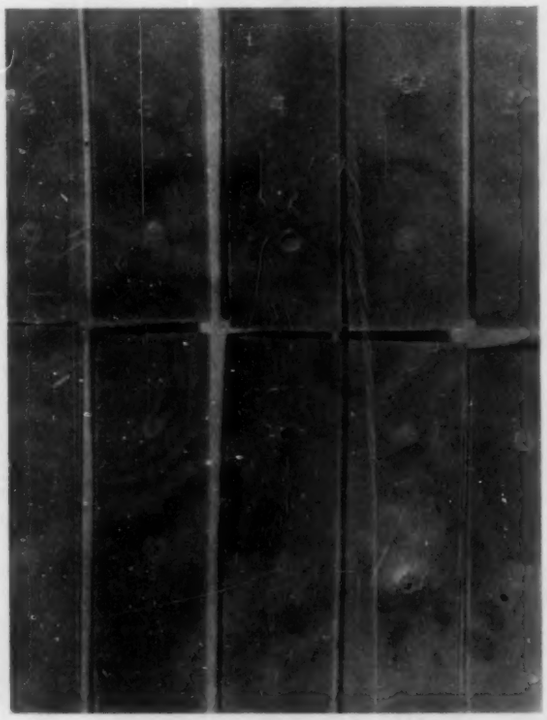

Fig. 6—Spot-Welded Specimens of Thin-Gage Duralumin after Fracture. Weld of Specimen 4 Remained Intact

Fig. 7—Microstructure in Weld of Duralumin Showing Typical Spot Weld of Good Quality. Note Original Grain of Duralumin at Right. Magnification 90 X. Etched in Aqueous Solution of 2.5% HNO_3, 1.5% HF, 1.5% HCl

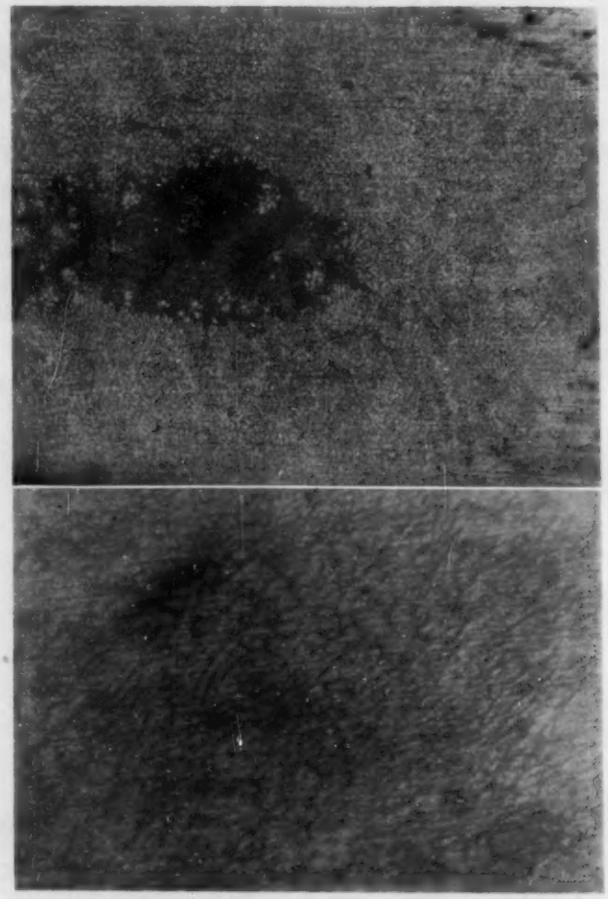

Fig. 8—Enlarged Micrograph of Weld in Fig. 7. Note Fine Grain of Aluminum and Disperse Form of Cu-Al Eutectic in the Intercrystalline Areas. Magnification 90 X. Etched with Same Solution as Fig. 7

The sequence of timing operations may be obtained by consulting the wiring diagram of Fig. 2, and the electrical transients for a typical welding operation appear in the oscillogram of Fig. 4. For each weld specimen the safety switch and main switch are usually closed. The specimen to be welded is clamped between the electrodes with the desired pressure, which is obtained by a method discussed under the welding unit. The current tap on the primary of the welding circuit is adjusted. The sequence of operations follows:

1. The control bus switch is closed. This energizes the 240-volt control bus, timer motor transformer and closes welding breaker No. 1 through timer unit No. 1, since the tap contacts of unit No. 1 are initially closed.
2. Then the motor switch is closed, which starts the synchronous motor drive of the timer. But the timer units do not rotate due to restraint of the release solenoid and the resulting slippage of the friction clutch.
3. The control selector switch is closed to either push-button control or oscillograph control. The "start" push-button as it is depressed initiates the timing cycle, since this energizes the control transformer and pulls the release solenoid down, which permits the friction clutch to set the timing discs No. 1, No. 2 and No. 3 in motion.
4. As disc No. 2 rotates the bottom contact of unit

No. 2 closes circuit breaker No. 2. The welder electrodes are energized, since breaker No. 1 was closed in step (1) above and now a time lag of at least 2 cycles exists. The breaker No. 2 completes the energizing of the primary of the welder.

5. After the timer has rotated through a distance predetermined by the relative settings of timer discs at No. 1 and No. 2 units, the tap contacts of unit No. 1 open and terminate the flow of welding current after a lag of one cycle. This value of time lag in breaker No. 1 is practically constant for no load and under welding conditions. The safety switch may be opened when removing the welded specimen.

6. When the timer completes one revolution, it locks in position for the next sequence of welding operations.

7. In checking the timing and power demands for welding, the control selector switch is thrown to the oscillograph control (Fig. 2) and the remote control functions when the push button is started. Four transients are obtained by connecting oscillograph elements (Fig. 2) to the circuits for primary voltage, primary amperes and breakers No. 1 and No. 2 transients.

Welding Unit

All specimens were lap welded in a conventional spot welder consisting of an enclosed transformer with short secondary leads which are attached to two sturdy electrode arms (Fig. 1). The upper electrode arm with its transverse water-cooled electrode is pivoted on the top of the transformer housing and the lower electrode arm is bolted in position on the front of the transformer housing. This lower electrode arm is fitted with a water-cooled electrode in a vertical position, to which the upper water-cooled electrode is aligned. The desired electrode pressure is obtained by compressing a calibrated spring, one end of which is stationary with the pedal latched in its lowest position. This spring is in a position between the extension of the pedal to the rear of the welding transformer and the extension of the upper electrode behind its pivot bearing, so that the pressure is transmitted through a screw thrust collar which is attached to the upper electrode mechanism. When the thrust collar is screwed down against the spring, the reaction due to the spring displacement is a measured amount. Electrode pressures of 39 to 151 lb. are readily obtained by appropriate spring adjustments. No measurable change of spring load was noticed before and after welding with the spring loading device.

Welding Tests

Small Templin grips for light metals limited the width of the specimen to $^5/_8$ in. Each specimen consisted of 5-in. lengths aligned in a jig and overlapped $^1/_2$ in. for welding in one centrally positioned spot. The resulting specimen was 9 in. long and tested for tensile strength in a 30,000-lb. Reihle Universal testing machine. Loading of this type of joint produces the most severe test on the weld and should develop the minimum limiting conditions for thin-gage duralumin.

With as many variables involved in the process of welding a metal as sensitive to heat as duralumin, a series of tests was undertaken to determine the combinations of factors which produce the optimum quality in a spot weld. For engineering design physical properties are considerations in so far as they are obtainable for diminutive welds. For uniformity of structure of the weld, metallographical studies assist in determining the condition of the weld as made. The metallographical study of the physical structure assists in selecting a sound weld and hence forming a judgment with regard to the best combination of the factors under consideration.

Three series of tests were performed in this investigation for three thicknesses of duralumin, namely No. 25 B & S gage, No. 24 and No. 20 gage.

Group I of specimens was welded with constant electrode pressure and time interval while varying the welding current.

Group II of specimens was welded under different pressures and current, with constant time.

Discussion of Results

The curves in Fig. 10 are typical of the process. The use of a common ordinate, on which appear values of current and seconds, $(I \times t)$ product, simplifies the manipulation of the number of variables in the process. The conditions of welding are demonstrated by the

Fig. 9—Microstructure of (17ST) Duralumin Sheet as Received. Elongated Aluminum and Aluminum-Copper Grains as a Result of Rolling Are Evident. Magnification 90 X

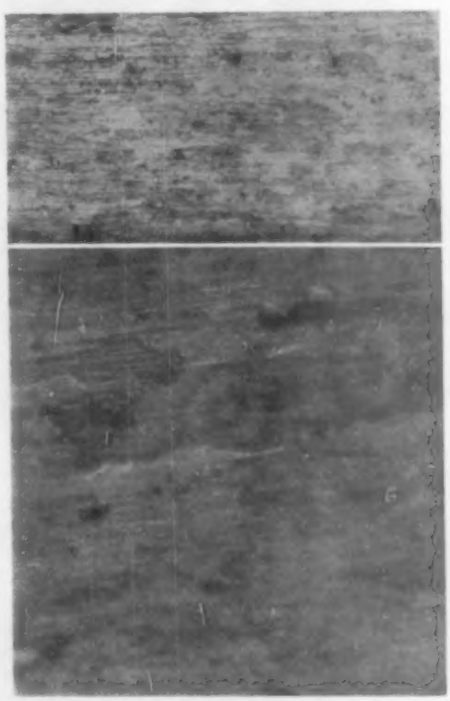

Fig. 9(a)—Microstructure of Thin-Gage Duralumin as Received. Magnification 570 X

curves drawn through simultaneous values of $(I \times t)$ product in coulombs and strength of lap joint on the right, and pressure at the electrodes on the left of the $(I \times t)$ product axis. The resulting curves are valid only for the duralumin of the gage thickness in the condition as investigated and for the same electrode in its details, such as kind, size and shape.

The nature of the process in other details may be analyzed from the curves. The process need not be materially altered except as for time of welding and electrode pressure in order to weld thin gages of approximate thickness, as study of strength curves (1) and (2) reveals. The curve has certain trends which indicate certain limiting conditions of the process—obviously, that the low $(I \times t)$ values develop low strength, especially when the electrode pressure is diminished greatly. The $(I \times t)$ supply is reduced by the amount of the excit-

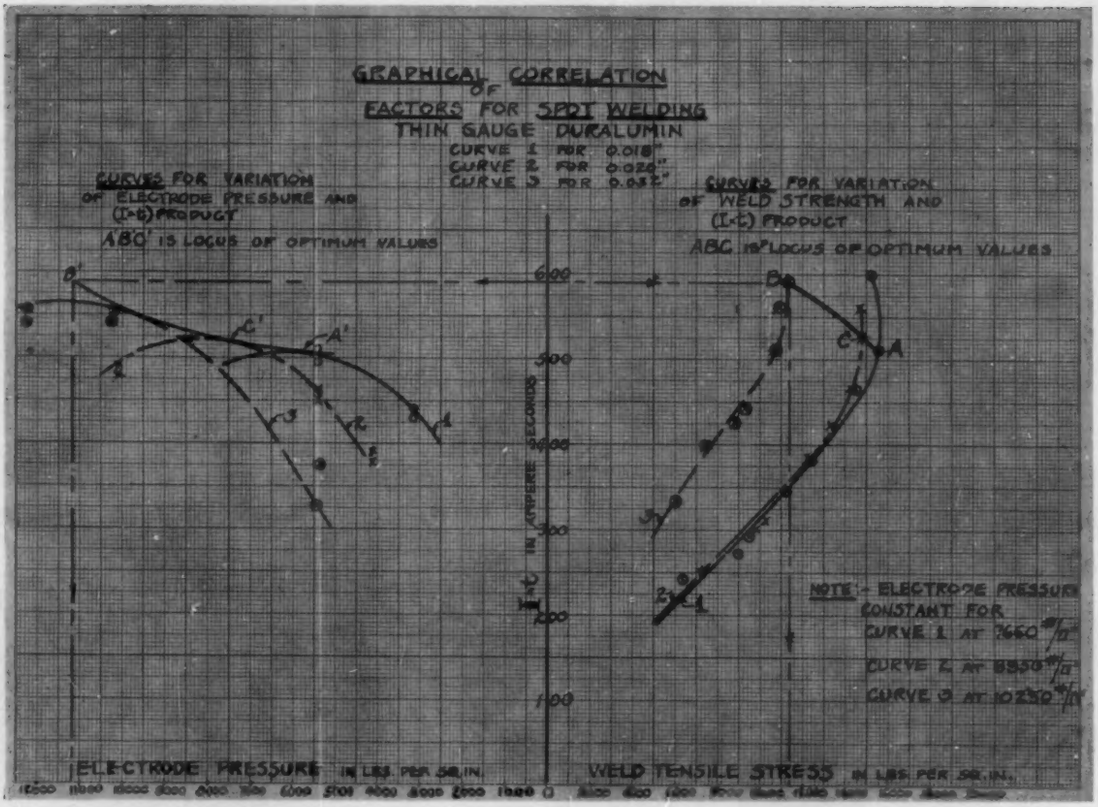
GRAPHICAL CORRELATION OF FACTORS FOR SPOT WELDING THIN GAUGE DURALUMIN
CURVE 1 FOR 0.018"
CURVE 2 FOR 0.020"
CURVE 3 FOR 0.032"
CURVES FOR VARIATION OF ELECTRODE PRESSURE AND (I·t) PRODUCT
ABC IS LOCUS OF OPTIMUM VALUES
CURVES FOR VARIATION OF WELD STRENGTH AND (I·t) PRODUCT
ABC IS LOCUS OF OPTIMUM VALUES
I·t IN AMPERE SECONDS
NOTE - ELECTRODE PRESSURE CONSTANT FOR
CURVE 1 AT 7660 #/in²
CURVE 2 AT 8550 #/in²
CURVE 3 AT 10250 #/in²
ELECTRODE PRESSURE IN LBS PER SQ. IN.
WELD TENSILE STRESS IN LBS PER SQ. IN.

Fig. 10

ing current for the transformer and is the terminal value at no load for zero strength and zero electrode pressure. However, the range of successful welding operation for the thicknesses of thin sheet duralumin is physically between A and B for physical properties, since this curve has been drawn as the locus of optimum strengths for the three tests. That there is the best current value which develops the proper fusion may be recognized when it is seen that the curve trend is toward lower strength for increasing $(I \times t)$ product beyond the optimum strength value.

Correlation of Basic Information.—This quantity may be reduced further. Due to poor electrical contact, the reactance drop at the juncture of the electrodes consumed as much as 0.43 volts for a submerged weld in Group III, or a kv-a. of 0.43 x $(I \times t)$ or 1270 product, which amounts to nearly 5.5 kv-a. dissipated reactance drop. This condition always is probable for light electrode pressure and is dissipated by burning the thin-gage duralumin. In other words the $(I \times t)$ product is a physical quantity which has real significance when the energy is utilized in heating the interfaces, directly by imposition of adequate electrode pressure to establish electrical contact between the plates and the electrode. These latter must be clean at all points of contact. A porous weld resulting from such causes is shown in Fig. 5. Lack of original homogeneity of the metal may have been a contributing factor.

The curves to the left shown in Fig. 10 are significant when considering the light-gage duralumin sheet in the following respects. Excessive pressure while establishing good electrical contact approaches a limiting condition when the large (It) product develops a plastic condition of the duralumin and crushes the weld or produces undercutting, which is detrimental. The limiting range of electrode pressure is shown by the $A'B'$ curve, which is drawn tangent to the curves for each individual gage. The simultaneous consideration of curves AB and $A'B'$ defines the limits of the spot-welding operation for these thin-gage metals. The values of all quantities except the heat were determined for Table 1 below

Table I—Tabular Summary of Findings for Lap Welds of Thin-Gage Duralumin

Thickness of Sheet	Lb.	Electrode Pressure Lb. per Sq. In. of 1/8-In. Electrode	Welding Time in Seconds	Welding Secondary: Current Amperes
0.018 or No. 25 B&S gage	66.5	5400	0.045	11200
0.020 or No. 24 B&S gage	94.5	7660	0.032	16400
0.032 or No. 20 B&S gage	135	11300	0.029	20000

Optimum Strength per Weld in Tension Lb. per Sq. In.	Heat to Weld in B.t.u.'s. Average Heat to Raise 1 Lb. Duralumin to Fusion Point = 0.065 × 1042, or 67.7 B.t.u.
15450	0.005
14600	0.006
11200	0.0067

from the curves in Fig. 10. When a horizontal line is drawn from A to intersection of locus curve $A'B'$, the simultaneous values of electrode pressure, $(I \times t)$ product and strength for conditions of the test are obtained. Similarly a line CC' yields the optimum values for No. 24 gage duralumin. Likewise a horizontal line to left from B to intersect curve $A'B'$ enables one to read the values of electrode pressure, strength and $(I \times t)$ product. The limitations inherent in this welding unit permit consideration of just these three metal gages. The welder

was operated at its capacity for the No. 20 gage metal, as may be seen by consulting data for these runs.

Metallurgical Phase of Spot Welding Duralumin.—A brief for the metallurgical transition is not possible in this limited space. But the metallurgical history is revealed in the photomicrographs of the accompanying specimens; some of the fractured specimens are shown in Fig. 6. A few duplicates of these specimens were examined for any departure from usual transformation in a spot weld. It was noteworthy that the actual weld was smaller in diameter than the electrode diameter in practically all of the specimens except those accidentally burned due to insufficient pressure or poor electrode tip surface. For instance Fig. 6, in which specimen 4 appears, shows a regular contour of spot weld but smaller in diameter than the electrode which held it. This specimen, like all the better ones, failed by pulling at the spot weld. The weld is uniform with a sharp contrast in microstructure between the shroud of unaltered plate metal on the surface and the core, which has been re-oriented by the welding impulse. This is true except for specimen 6*a*, which reveals a porous interior and centrally localized core of refined metal. The duplicate of this specimen is shown in the photomicrograph of Fig. 5. The grain between this core and the outside consists of large-grained masses of aluminum and aluminum copper with undesirable variation in grain size, which is clearly revealed in Fig. 5*a*, which shows some eutectic melting. The weld has been subjected to corrosion in 2% saline solution and within a week has begun to deteriorate.

The welds of Figs. 7 and 8, which were not welded under water, show greater immunity than those subjected to water cooling during the weld placement. The grain of these welds in Fig. 8 appears to be more uniform and finer grained in microstructure, due to slower and more even cooling, than received by water-cooled specimens.

Summary

Spot welds of high quality are produced under accurate control. The strengths, resulting from a systematic procedure, are uniform and produce welds in clean metal which is homogeneous. An analysis of these conditions has developed a very simple method of solution for the principal variables in the spot-welding process. With the elementary facts established in workable form, further intensified use for welding ultra-light structures is anticipated.

Acknowledgments

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Data for Resistance Welding of 17ST Thin Gage

Specimen No. 25 Gage	Pressure in Lb. per Sq. In., 1/8-In. Electrode	*I* (Second Current)	*t* (Time in Sec.)	*I* x *t* (Amp. Sec.)	Weld Strength	
1	7660	5340	0.045	241	6100	
2	7660	5710	0.045	257	8950	
3	7660	6340	0.045	285	9440	
4	7660	7650	0.045	344	11150	
5	7660	8050	0.047	376	12300	
6	7660	10200	0.045	460	14150	
7	7660	12390	0.039	503	15450	
8	7660	13200	0.045	595	15150	
1b	3150	9660	0.045	434	13100	
2b	3150	9580	0.045	432	12800	
3b	5400	11350	0.045	510	14400	
4b	5400	10900	0.045	492	14640	
5b	7660	10900	0.045	490	See 4	
6b	7660	9100	0.045	410	11450	
7b	10250	7140	0.045	323	8550	
8b	10250	7320	0.045	329	9450	
Specimen No. 24 gage	8950	7780	0.032	249	7200	
10	8950	8320	0.032	266	9050	
12	8950	9160	0.032	293	9800	
13	8950	9480	0.032	304	10200	
14	8950	11930	0.032	382	12550	
15	8950	13120	0.032	420	13120	
16	8950	15170	0.032	485	14350	
17	8950	16300	0.032	521	14700	
18	8950	14340	0.039	560	14600	
10a	4070	11880	0.032	380	12200	
11a	4070	11750	0.032	376	11600	
12a	5400	12600	0.037	467	14100	
12a	5400	14100	0.032	451	13960	
13a	8950	See 17	0.032			
13a	8950	16100	0.032	515	14600	
14a	10250	14880	0.032	476	14000	
14a	10250	14460	0.032	459	13840	
Specimen No. 20 gage	10250	11380	0.029	530	5990	
19	10250	13570	0.029	394	7400	
20	10250	14400	0.029	419	8840	
21	10250	17680	0.029	441	9300	
22	10250	16660	0.029	483	7600	
23	10250	20500	0.025	512	9700	
24	10250	22700	0.025	567	10800	
25	10250	17810	0.032	590	11200	
26	10250		0.034		Specimen undercut badly	
19a	5400	11380	0.029	330	4750	
20a	5400	16400	0.029	475	5810	
21a	8950	17050	0.029	494	6220	
22a	8950	17520	0.029	508	6450	
23a	10250	18830	0.029	545	8920	
24a	10250	19150	0.029	555	9360	
25a	12300	18630	0.029	540	9100	
26a	12300	18220	0.029	527	8740	
Watercooled 27	7660	6430	0.131	844	8790	
28	7660	6660	0.151	1010	8460	
29	7660	10900			9600	undercut
30	7660	8550	0.138	1180	7320	
31	7660	9200	0.138	1270	11800	undercut
32	7660	5050	0.201	1015	7890	

Original Duralumin 17ST. Ultimate Strength = 49,100 lb. per sq. in. Elongation = 13.2% in 2 in.

Qualifying Pipe Welders*

By Dr. S. LEWIS LAND† and JOHN H. ZINK††

OUR contribution to the symposium on "Qualifying Pipe Welders" in accordance with requirements of various Codes will be primarily concerned with qualifying our own pipe welders to meet the requirements of the Heating, Piping and Air Conditioning Contractors Industry under the "Code for Pressure Piping" proposed by the American Standards Association and the "Specifications and Standards" of my own National Association.

This preliminary statement implies and intends to except from consideration the cross-country pipe-lines where the rotating type of weld predominates, and the supplemental mechanical apparatus used in the actual welding operation removes much of the responsibility from the individual mechanic. It is only in exceptional cases that we are able to use this type of welder to advantage without much additional education and training.

Both the Pressure Piping Code and our own Specifications and Standards recognize in the final analysis that the contractor and not the mechanic is responsible for the quality of the welding done, and this is as it should be. Nothing in our program indicates any desire to shirk this responsibility.

The proper qualification of our pipe welders involves three important stages—selection, training and testing. As a necessary supplement we add an intensive educational program for the contractor.

Selection of Pipe Welders

Obviously, the selection of the right men is the first and most important step. We recognize at once the fundamental soundness of the decision of the American Federation of Labor, from both an economic and industrial standpoint, that welding as a process is simply another method of pipe fabrication and installation—not a separate and distinct trade; and that it belongs to the recognized trade in which the process is employed. Our whole program is accordingly built on the basis of making welding "specialists" out of our present steam-fitters and helpers, and, of course, adding welding to the training courses of apprentices who are undergoing a five (5) year training program to become journeymen mechanics. I use the word "specialist" to elevate the good welding mechanic into the position of an artisan to differentiate him from the class literally developed overnight for the purpose of insuring the sale of a particular welding apparatus or, I regret to admit, by contractors who don't know what it is all about and apparently don't care.

It is not our belief that all steam-fitting mechanics should be trained as welders. The ability to weld in our field requires physical and educational qualifications not possessed by all our men, nor do the needs for pipe welders justify the training to this extent. Even with this care in selection, our mortality rate will be relatively high. Consequently, we select from our personnel those men who are best qualified by physical and mental ability and put them through an intensive course of training. The number selected will average from twenty (20) to thirty (30) per cent of our employee group.

Physical Requirements

Candidates for training are preferably selected from those between the ages of 18 and 35. They should be strong in body, have good eyesight, steady nerves, good endurance, ability to work in tight places and a satisfactory amount of pipe-fitting intelligence.

There are exceptions to the upper limit of this age requirement, but older men as a rule do not have a whole-hearted desire to learn new methods, and they usually confront us with all the difficulties to be expected in "teaching an old dog new tricks." Exercising care as to limitation of age tends to reduce the mortality and expense, and these factors must be considered if we are to obtain proper return for our investment.

Good eyesight is required because of its advantages in fitting, alignment and measurement, and as a protection against the misuse of the man's own safety appliances which many times occur in spite of warning and intermittent supervision. Good nerves and endurance are essential because the handling and mechanical manipulation of welding tools and stationary or awkward positions in welding are exacting and trying to both. Cleanliness of person, close fitting clothing and reasonable knowledge of fire hazards are also necessary considerations. The diversity of our work many times subjects the welding mechanic to toxic fumes, poor ventilation and dangerous conditions of plant operation which makes it necessary for us to give major consideration to the physical development of our selected men. And it usually follows that his degree of physical fitness determines the operating fitness of the apparatus he is using.

Educational Requirements

A technical education is not required, although it is desirable. It is not unusual for us to develop a good welder with practically no education, and in that case we strongly recommend an educational course for him either by attending vocational or night schools or, in lieu of these, individual help in the contractor's shop. Shop conferences, authoritative books and freedom to do experimental work in the shop under friendly and encouraging conditions, all aid materially in his education. He should be equipped with an elemental knowledge of the chemistry and physics involved in making a good weld so that he may know the functioning factors of the parent or base materials to be welded; the effect of temperature; a fair knowledge of the common metals to enable him to determine whether they should be welded or brazed; and the proper process to use by knowing their limitations; and a good performance knowledge of welding rods.

* Paper presented by John H. Zink at Fall Meeting, A. W. S., Oct. 1–5, 1934, New York.

† Educational Director, Heating, Piping & Air Conditioning Contractors National Association.

†† Vice-President of above Association.

He should also have a fair understanding of related mathematics, be able to interpret blue-prints and make patterns and templets for special connections; and, since in many localities he works alone on certain work, it is essential that we develop in him and expect him to deliver the same ability to design, plan and perform as we do our steam-fitting mechanics.

It must not be assumed from the foregoing that we expect to give him the educational background of a college professor as well as a workman. We ask no more from him than we do from our good steam-fitters, and it includes the necessity and ability to use his head as well as his hands. The proper use of the welding process demands headwork as well as labor; and, since we expect to develop an efficiency of approximately eighty (80) per cent, over an eight (8) hour working period with due allowance for job peculiarities, you can readily see that we must equip him beyond the actual welding application. Otherwise, we unnecessarily load the job with labor. I need only point out to you that in many Metropolitan areas under jurisdiction of the Trade Unions a welding mechanic must carry a helper with the additional burden of restriction to actual welding and no privileges in handling piping materials for erection. The result is that work done in these localities is performed with four (4) men when two (2), at most, could do it to best advantage. You can readily see the economies of welding are lost under this working plan; this loss is attributed to individual and indifferent methods of planning and education. When you circumvent the legitimate channels through which welding should be directed for selfish reasons you antagonize labor and create a vicious competitive situation between contractors and owners. This situation is so real and so unfair to welding as to suggest better coordination between the sponsors of the welding process.

Training Pipe Welders

As soon as our training group is selected, approximately meeting these requirements, we plan a training period usually lasting from 120 to 180 hrs. The division of that time will depend on the type of program, whether the training is being given by the contractor in his own shop or in an approved vocational school.

If the training is given in the contractor's shop, it is essential that the contractor's own knowledge qualifies him as an instructor or he must provide it from outside sources. Training programs, to secure efficient results, must be well organized and provision made for systematic instruction. Our Educational Department gives valuable assistance to the contractor covering all phases of his shop training. If the contractor does not desire to assume this training obligation through lack of qualification or inability to make the money expenditure, we do not hesitate to urge him to seek some part of this help from our manufacturing friends. We insist upon this supervision help because mere practice at cutting and welding, without accompanying instruction, is not sufficient and may well give birth to wrong habits and skills which may be very difficult to correct.

If the training is given in an approved evening vocational school, we suggest a minimum period of instruction covering 36 weeks, two hours twice a week, a total of 144 hours. It is assumed that, particularly during the latter part of his training program, the trainee will have an opportunity to do much actual welding to gain practical experience as well. In my own case, we make available our shop facilities without cost to give him this experience and, equally important, confidence in himself. He sits in on our shop conferences, which are held at least once every three weeks on my time and not theirs, and thus we take the "kinks" out of the things he doesn't understand or misconstrues.

It is well to mention here that the minimum training and experience of instructors in vocational schools should be the equivalent of that required for shop and related subject instructors as set up in the State plans for Vocational Education. Our National Association has followed the vocational training of welders energetically and with much help, and not only have we been able to have welding courses established in vocational schools in many cities but have been shown the courtesy of supervising and recommending the training course. It is my personal opinion that as this type of vocational training grows we will bring into our industry welding mechanics with educational training and skill to better plan and perform good welding work. There is no intent here to belittle the self-made mechanic, but just as welding has improved our method of pipe installation so will the educated mechanic improve our standards of work.

The course of study approved by our National Association is divided into sixteen (16) units of instruction. The first five (5) units may be presented as group instruction at the beginning of the course, and thereafter as individual instruction as occasion requires. Units 6 and 16 are given as individual instruction. No trainee should be permitted to advance from one unit to another until he has proved to the satisfaction of the instructor that he has the required ability to do the particular job. The 16 units involved in the course of training follow:

Unit No. 1.—Study of the development, application and process of pipe welding and cutting.

Unit No. 2.—Study of the various items of apparatus and equipment and their uses.

Unit No. 3.—Study of the various items of welding materials and supplies.

Unit No. 4.—Study of precautions and safe practices.

Unit No. 5.—Study of the ability to assemble and adjust apparatus (2 job sheets—one on setting up welding and cutting units and one on adjustment of pressure and flame).

Unit No. 6.—Cutting and welding of steel plate.

Unit No. 7.—Cutting pipe—steel pipe in sizes 2 and 4 in.

Unit No. 8.—Cutting bevel on pipe—sizes 2 and 4 in.

Unit No. 9.—Making a rotating pipe weld in horizontal position. Ability to cut, bevel and weld 2, 4 and 6-in. pipe.

Unit No. 10.—Study of and practice in the use of templets.

Unit No. 11.—Cutting branch openings for Tee intersection assemblies.

Unit No. 12.—Welding branch connections—45 and 90-deg. angles.

Unit No. 13.—Making a position weld in horizontal pipe—2, 4 and 6 in.

Unit No. 14.—Making a weld in vertical pipe—2, 4 and 6 in.

Unit No. 15.—Overhead welding.

Unit No. 16.—Welding pipe headers including cutting to measurement.

There are too many varying conditions in different localities for us to compile reasonably accurate cost figures per man covering his training expense. Conditions of labor, free help from outside sources, amount of expense absorbed by contractors, etc., all tend to make average figures unreliable. In my own case, I know I have an average of $300.00 cash investment in each of my graduated welders without consideration to my complete loss where mechanics fail to make the grade.

You, of course, realize as I do that the efficiency of a welder is largely determined by the amount of welding he is called upon to do. If it is a minimum, he is apt to go stale or you may lose him to a competitor. Once he masters the art of welding he is reluctant to do other kind of work. To cope with this situation as well as avail myself of the economic advantages of welding, I am organized on a strictly welding basis, and no matter how I am compelled to estimate a job, I use my best efforts to convert it to a welding installation. This gives me a better continuity of welding work, assures me of definite and comparative costs, and my welding mechanics make as much time as do my steam-fitting mechanics; and I need not explain to you what this means to me from the standpoint of satisfied labor.

Testing Pipe Welders

It goes without saying that all pipe welders should be tested at regular intervals during their training and at reasonable times thereafter during their employment. I will not elaborate on the approved tests covered in detail in the Specifications and Standards published in our "Standard Manual on Pipe Welding," but I would like to bring to your attention my objections to some of the silly demands under the head of testing predicated upon ignorance or the exercise of arbitrary powers.

I have no objection to coupons being cut out in cross section from welds made from scrap pipe either in the shop or in the field for the sole purpose of testing. I do object strenuously to these coupons being cut out of completed installations. In the first place, removing these coupons is a dangerous practice because of the slag deposited on the inside of the pipe which may cause considerable damage to valves and other auxiliary equipment. Replacement of the patch is also generally something not to brag about. I recommend that the entire weld be removed with a 6 or 8-in. section of pipe either side of the weld, and the replacement be made with a spool piece of new pipe and two circumferential line welds. Aside from the fact that one coupon may not tell a true story of a poor weld, the questionable quality of the replaced patch and finished appearance of the work should discourage the practice as a black eye on welding. I would much rather assume the initial expense to keep my reputation intact and avoid the possibility of backcharges.

I strongly recommend also a service test on a partially completed or fully completed installation where possible rather than the hydrostatic or air test. This can be done in sections where necessary with valve closures and before insulation is applied. It is not always convenient or economical to make an air or hydrostatic test. For example, it would be foolhardy to test with water or air the exposed piping in a large building operation in New York during zero weather. Too often specifications are written giving the owner or his awarding authority options of selecting either the hydrostatic or service tests, and in some cases both, with accompanying language indefinite enough to permit the widest range of interpretation and, consequently, a wide range of estimating cost on the part of the contractor as to the cost of testing. This permits inequality in bidding and the arguments that follow do not inspire confidence.

The question of certifying a good welder so that he does not have to be subjected to the same qualification tests each time he desires to go to work is something that has given me much concern. During the stress period of the last four (4) years, it is not unusual for a good welding mechanic to work for as many as five (5) contractors in one month. It is not fair to him nor is it fair to us to burden us with the expense of a five-time test on the same man within one month. Either we must within our industry give this man a certificate or card to protect and give him proper rating or we must send his welds to be tested to an accredited and independent testing laboratory if strict neutrality is desired. Such a procedure and requirement might well be given serious consideration by the sponsors of welding so as to encourage uniform practice at a minimum of expense.

Welding rod remains somewhat of a free lance under our pending Codes. We are told that the analysis of the rod as manufactured is not a true criterion of its value after deposit. I well realize the practical difficulties encountered by the Code makers in dealing with this problem, but the irony of it all is that the contractor must assume all the responsibility for a product over which he can exercise but a minimum of control. Until the research divisions of the welding industry clear up present uncertainties, I favor some form of welding rod certification to guide us in our purchase so as to minimize "passing the buck" due to divided responsibility, and perhaps taking advantage of our admitted ignorance is another justification for this appeal. Too often have I seen good welders innocently pay the penalty for the results of using poor quality welding rod, and in this respect I pay my compliments to the astute salesman who, for volume sales and personal commissions, elevates inferior welding rods to the exalted position of welding everything including a broken heart.

The technique employed by mechanics is not specifically covered in pending Codes and is usually left to individual habits. Proper penetration and fusion of a pipe weld involves a fundamental knowledge of temperature regulation, spacing, flux control, a very definite knowledge of the over-lapping requirements to properly close a weld, apparatus adjustments and, in the case of flange attachment and intersection welding, ability to normalize a weld for the distribution of stress and to reestablish alignment. I certainly will not permit a welder to work for me who violates the very definite procedure of my shop covering these factors of technique. We have definite knowledge in our industry to establish substantially uniform technique, and I am, therefore, not in favor of encouraging questionable individualism.

From the standpoint of management, promotion, design and costs, the contractor cannot escape his obligations of knowledge, organization and finances; and these demands are equal in importance and bear direct relation to those required of him in gaining his reputation under our older methods of pipe erection. Buying a welding outfit and trusting to luck is not sufficient qualification for a contractor, or anyone else, to enter the welding field. So long as we neglect this very necessary phase of our instructional program, we impose upon the contractor two practical and very perplexing problems.

First, discord in the ranks of the contractor's employees who soon realize they are the brains of his welding activities, and may readily assume an arbitrary position and resent supervision and instruction to the point of being discharged or quitting to become a contractor and creating additional competition. Second, the contractor may have brought home to him forcibly that he is losing money on his welding operations and discontinues using the process. And as is to be expected, he advertises that the process is to blame, and rarely will he confess to his own shortcomings. This is further aggravated when we equip him with false information as to costs, and we shut our eyes to the plain truth that too much poor welding is getting by.

Any program that concentrates instruction on the mechanic and excludes the contractor falls short of our requirements and seriously interferes with our efforts to unify and dignify the process in our industry.

Some Measurements of Residual Stress in Arc-Welded Steel Plates

By R. E. JAMIESON†

IT IS well known that the arc-welding process, as used in the fabrication of steel work, sets up residual deformations in the parent shapes. In many cases the observed deformations are so large as to preclude the possibility that they represent elastic strain only, and it becomes evident that they must be made up in part by elastic strain and in part by permanent or plastic deformation, even at points relatively remote from the weld. Elastic strain, remaining in the material after fabrication, represents the zero condition upon which will be superposed the elastic strains set up by applied working loads, with consequent modification of allowable load for any given allowable working stress. On the other hand, material which has undergone plastic deformation may, within limits, be considered to be in the condition of zero initial stress assumed in design theory. It was the object of the present investigation to apportion into these two classes the residual strains observed in certain simple welded specimens. The elastic residual stresses inferred from the strain measurements were component stresses such as are computed in ordinary design, rather than localized principal stresses.

The specimens were as simple as possible, consisting of rectangular plates provided with machined grooves on two parallel edges. On filling the grooves with weld metal, the plates would undergo deformations, principally in the direction parallel to the welds. These deformations, made up in part of elastic strain and in part of plastic deformation, were measured. After the completion of these measurements, the plates were sawed into strips parallel to the welds. As each strip was severed from the parent plate, it would change in length by the amount of the average elastic strain in the direction of the saw cut present in it while still attached to the plate. Any failure to recover to its original length could be ascribed to plastic deformation. All saw cuts and measurements were made in the direction parallel to the welds, so that the results obtained give some idea of the component conditions existing in the plate in this direction, after the application of the weld metal. The figures for residual stress are, therefore, of particular interest for those cases in which the direction of the weld in a joint is parallel to the applied stresses caused by external loading.

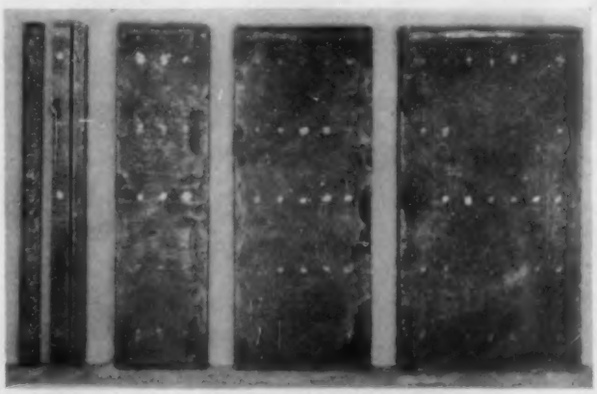


Fig. 1—Test Plates in Series I

† Professor of Civil Engineering McGill University, Montreal.

In all cases the plates of a series were cut from the same stock, the grooved edges were parallel to the direction of rolling and the weld metal was applied by one operator. Measurements of initial total deformation were made on a linear comparator. Measurements of the recoveries in the lengths of the severed strips were made on a comparator in Series I and with a 10-in. Howard strain gage in Series II. The measurements were made on both faces of each plate, and the means of corresponding readings were used in computations and diagrams.

Series I[1]

This consisted of four plates, each 15 in. long and $^7/_8$ in. thick, of widths 2, 4, 6 and 8 in., respectively. They are shown in Fig. 1 and were used as received from the rolling mill. All welding was by means of bare electrodes in a single pass, the welding being applied continuously over about one-half of the length of one groove at a time. Details of grooves and locations of measuring points are shown in Fig. 2, and average stress-strain characteristics, both of plate metal and of weld metal, in Fig. 3. The plate-metal coupon was from the central strip of the 6-in. plate, and the sample of weld metal was turned down from an outer strip sawed from the 2-in. plate. Thus, the characteristics shown represent the conditions of the materials after undergoing plastic and elastic deformation and after being relieved of the elastic strain.

The changes of length in each gage length of the 12 in. under observation, as measured after welding but before cutting into strips, are plotted in the isometric diagrams of Fig. 4. The ordinate at the mid-point of a 3-in. gage length represents the shrinkage, in inches per inch, for that gage length. The upper ends of the ordinates have been joined by straight lines as an aid in reading the diagrams.

The full line in Fig. 5 shows the elastic recovery in the length of each strip of the 6-in. plate, plotted to scale as ordinates from the zero line. The average changes in length in the observed 12 in., in inches per inch, are multiplied by modulus values of 28.0 and 29.2 million lb. per sq. in. for the bare-electrode deposited metal and plate

[1] By D. E. Evans, Mech. Engr. (McGill), 1933.

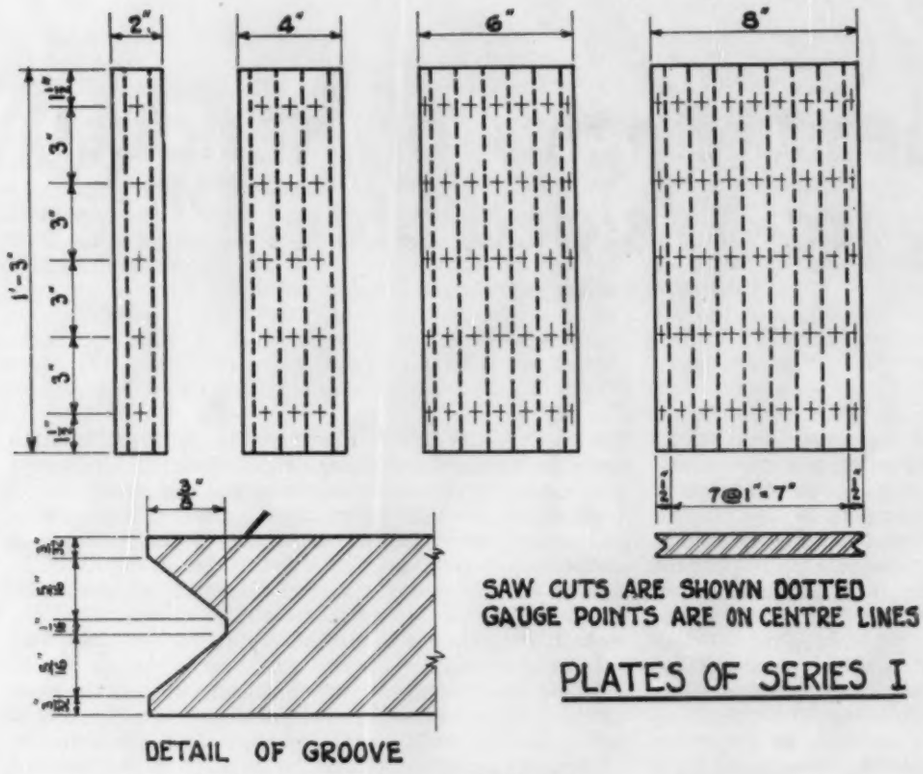


FIG. 2

metal, respectively, to obtain the scale of unit stress to which the ordinates are plotted. Increases of length, indicating initial compression stress, are plotted above the zero line, and initial tension stress below this line. The curve thus obtained represents the variation of residual stress across a section of the plate, assuming that this stress is uniform over the cross section of any strip. As the thickness of the plate is the same for all strips, the area of the cross section of a strip is proportional to the width of the strip, so that the areas of the diagram between zero line and curve, being proportional to the products of average unit stress and cross-sectional area, represent the total longitudinal elastic forces existing in the plate before cutting, that is, after welding and cooling.

To satisfy the conditions of equilibrium, the summation of the elastic forces parallel to the saw-cuts and the summation of the moments of these forces about a point in their plane, should be zero. The area above the base line represents a compression force of 12,800 lb., and that below the base line a tension force of 13,100 lb. The summations of the moments of the forces about the left edge of the plate are, respectively, +39,600 in.-lb. and −41,200 in.-lb. These figures constitute a very satisfactory check on the accuracy of the experimental work. They necessarily include instrumental and observational errors, which, in the case of measurements of elastic recovery, and converted into terms of stress, are estimated at a probable value of plus or minus 300 lb. per sq. in.

All strips as cut off remained straight, with the exception of the half-inch outer strips containing the weld metal, and, in some cases, the strips immediately adjacent to these. In every case the weld strips bowed appreciably in the plane of the plate, the cut face of the strip becoming concave. In those cases where adjacent strips showed measurable bowing, the curvature of the inner strips was in the opposite direction. Such bowing indicates a substantial difference in stress across the width of the strip, with a higher tension stress along the line of this first saw cut than on either the exposed welded face or the inner face of the adjacent strip. An estimate of this stress difference was made by measuring the curvature of the strip and assuming that the bending moment causing this curvature was constant throughout the length of the strip. Referring again to Fig. 5, the dotted line represents the variation of residual stress across the 6-in. plate, after taking these stress differences into account. The corrections were applied only in the cases of the weld strips and adjacent strips. No measurable bowing was observed in the three central strips, although, of course, some small amount must have been present. The dotted line shows the form of stress distribution which is typical for all the plates of Series I, and for those plates of Series II which were not stress-relieved.

Series II[2]

This series consisted of eight plates, each 12 in. wide, 21 in. long and $^3/_4$ in. thick. All were cut from the same stock and treated as rolled. The grooves, which differed slightly in profile from those of Series I, were along the 21-in. edges and parallel to the direction of rolling. The principal object of this series was to throw some

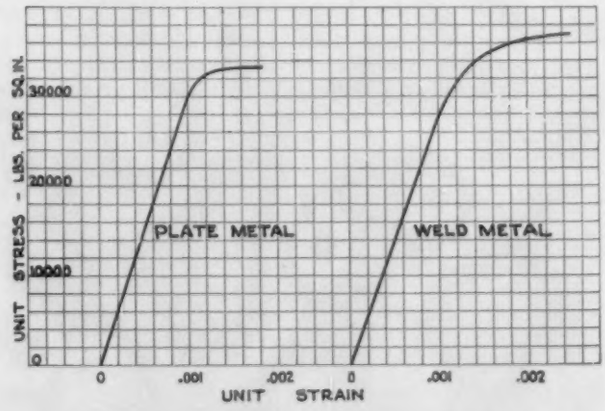


	PLATE METAL	WELD METAL
YIELD POINT	33,300	36,700
ULTIMATE STRENGTH	60,500	53,500
MODULUS OF ELASTICITY	29,100,000	27,800,000

Fig. 3

[2] By L. Jehu, Mech. Engr. (McGill), 1934.

light on relative conditions resulting from differences in procedure. Accordingly the plates were treated as shown in the table:

Plate	Welding Treatment	Amps.	Open Circuit Volts	After-Treatment
1-b 1-pass	bare electrode	160	62	None
2-b 2-pass	bare electrode	160	62	None
1-c 1-pass	covered electrode	175	62	None
2-c 2-pass	covered electrode	175	62	None
1-b 1-pass	bare electrode	160	62	Stress-relieved
2-b 2-pass	bare electrode	160	62	Stress-relieved
1-c 1-pass	covered electrode	175	62	Stress-relieved
2-c 2-pass	covered electrode	175	62	Stress-relieved

The electrodes were all $^3/_{16}$-in. diameter. Weld beads were applied over one-quarter length of groove at a time, and staggered. Measurements were confined to the central ten inches of length, leaving $5^1/_2$ in. at each end outside the measured zone. This was because Series I had indicated the presence of complex conditions near the free ends of the plates. The stress-relieving of the last four plates consisted of slowly heating them in an oven to a temperature of 1150° F., holding this temperature for one hour, and then slowly cooling them. Outer strips, containing the weld metal, were $^1/_2$ in. wide, and remaining strips 1 in. wide, as in Series I. It was found necessary to use chill-bars when welding with covered electrode, in order to avoid burning the edges of the grooves.

The plate material was somewhat softer than that of Series I. Its characteristics, shown in the following table, were determined from samples after the welding and sawing were completed.

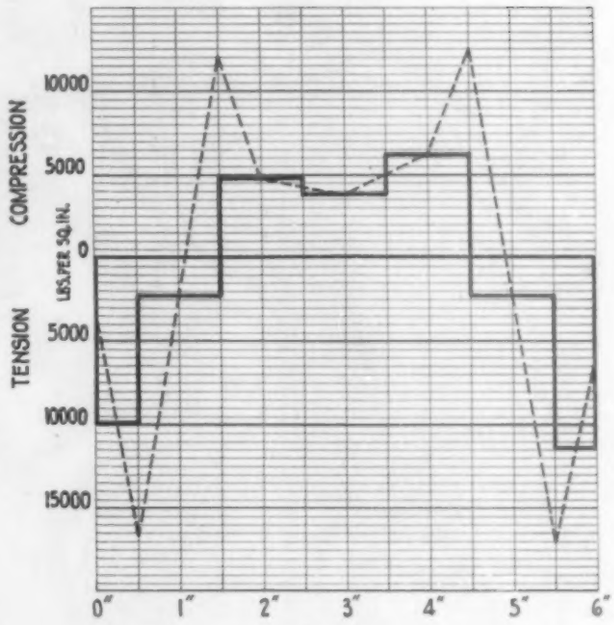
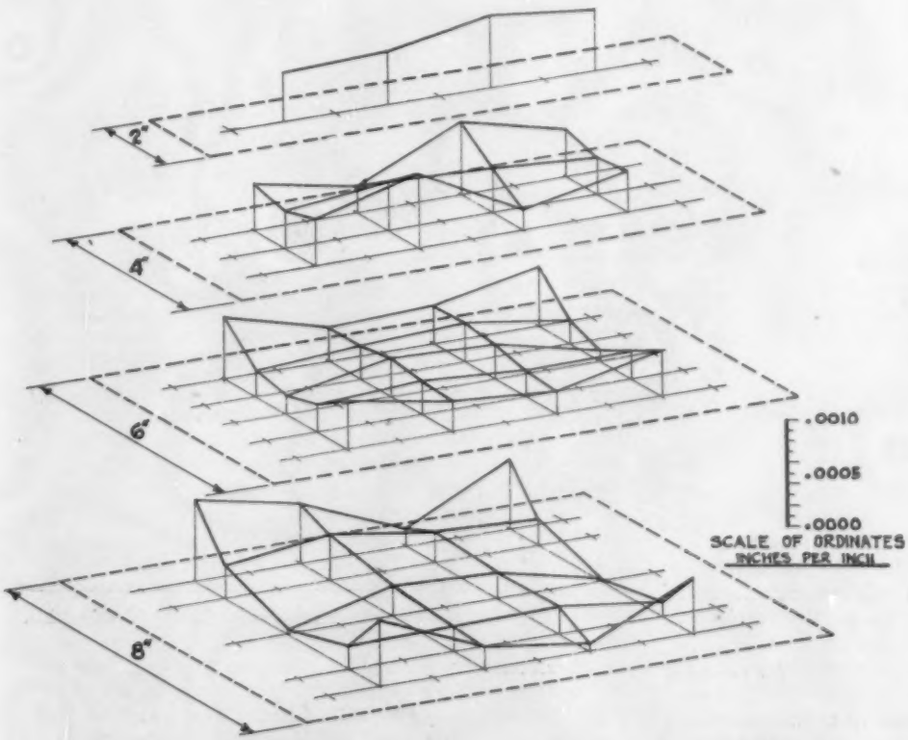


FIG. 5

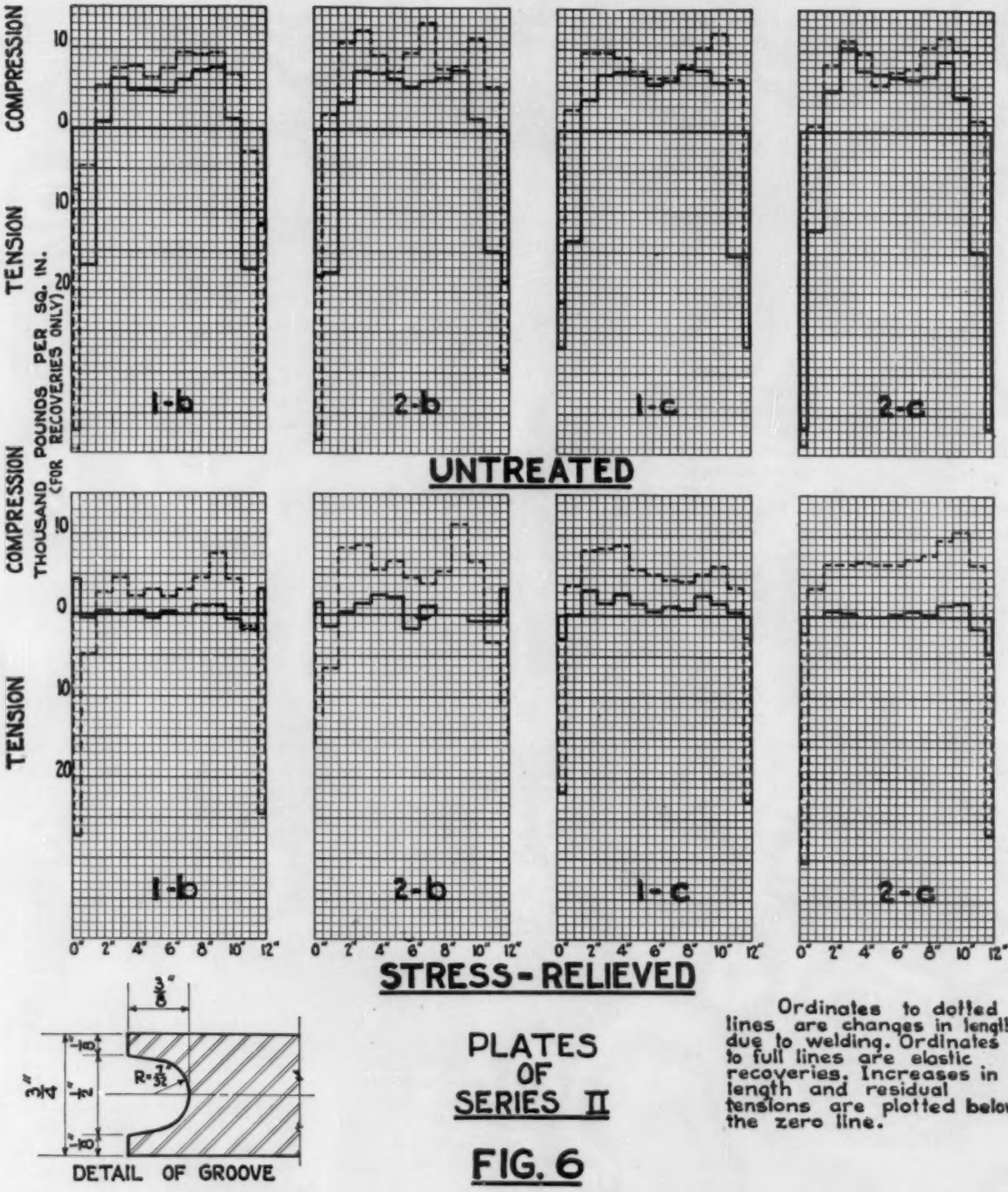
	As-Rolled	After Stress-Relieving
Yield Point (drop of beam)	33,300	31,050
Ultimate Strength	51,500	50,900
Elongation in 8 in.	32.3%	31.1%
Reduction of Area	67.0%	65.0%
Modulus of Elasticity	29,300,000	29,200,000



SHRINKAGES IN PLATES OF SERIES I

FIG. 4

Figure 6 shows the deformations due to welding, and the elastic recoveries after cutting, as measured on the several strips of each plate. The scale of unit stresses, applicable to the elastic recoveries only, is based on modulus values of 28.0 and 29.0, and 29.2 million lb. per sq. in. for bare-electrode deposited metal, covered-electrode deposited metal, and plate metal, respectively. Ordinates to the dotted lines represent the differences of the measured lengths before and after welding in the case of the untreated plates, and after stress-relieving in the case of the relieved plates. Increases of length are plotted below the base line, and decreases above the base line. The scale used is the same as though these deformations had represented elastic stress, so that the relative ordinates to dotted line and full line indicate the true proportion between total deformation and elastic recovery. In the diagrams for plates 1-b, untreated, and 2-b, stress-relieved, the dotted lines at



PLATES OF SERIES II

Ordinates to dotted lines are changes in length due to welding. Ordinates to full lines are elastic recoveries. Increases in length and residual tensions are plotted below the zero line.

FIG. 6

the weld strips are not closed, as no measurements of deformation were available for these strips owing to damage of the measured points during welding.

Summations of elastic force parallel to the saw cuts are shown in the table at the right.

These summations, and also those of moments about one edge of the plate, for the plates which were not stress-relieved, balance satisfactorily, as in Series I. The checks are not satisfactory in the cases of the four stress-relieved plates, but it will not be noted that many of the

	Plate	Compression, Lb.	Tension, Lb.
Untreated	1-b	33,000	32,800
	2-b	37,500	38,600
	1-c	44,400	42,000
	2-c	47,800	47,900
Stress-Relieved	1-b	5,900	2,000
	2-b	7,600	2,900
	1-c	12,700	2,000
	2-c	4,700	3,500

elastic recoveries in the strips of these plates are very small, approximating the probable error in the measurements.

It is interesting to note that all the observed elastic stresses in the stress-relieved plates are below 5000 lb. per sq. in., which is approximately the proportional limit for the metal at the stress-relieving temperature of 1150° F.[3] Bowing of the half-inch outer strips occurred, as in Series I.

Average Total Shortening

While there was in every case considerable variation of change of length between corresponding gage points across a plate, it may be of interest to compare the averages for each plate. In the following table are shown the average changes of length for the central portions of the plates, being the average differences between the measurements taken before and after welding. These changes were shortenings in every case. The deformations of the weld strips are omitted from these averages. The percentage of weld shown is the ratio of weld sectional area to parent sectional area. The instrumental probable error is estimated at 0.000015 in. per in.

	Plate	Condition	Average Shortening In. per In.	Percentage Weld Metal
Series I	2 in.	As-rolled	0.000555	0.195
	4 in.	As-rolled	0.000422	0.089
	6 in.	As-rolled	0.000311	0.058
	8 in.	As-rolled	0.000312	0.043
Series II	1-b	As-rolled	0.000192	0.034
	2-b	As-rolled	0.000299	0.034
	1-c	As-rolled	0.000275	0.034
	2-c	As-rolled	0.000268	0.034
	1-b	Relieved	0.000091	0.034
	2-b	Relieved	0.000163	0.034
	1-c	Relieved	0.000200	0.034
	2-c	Relieved	0.000243	0.034

Inasmuch as these figures are averages of widely varying values, only general comments on them are permissible. It may be noted that the average shortening appears to vary with the percentage of weld metal applied, and that the stress-relieving reduces the shortening substantially in most cases.

Observed Elastic Stresses

Here again the variations in values across any plate must be borne in mind. In particular, the high stresses observed near the root of the weld are applicable only to a very narrow band. The following table shows the observed maximum stresses with their locations, and are those taken as uniform across the respective strips in plotting the diagrams in Figs. 5 and 6.

The values of the stresses observed in the stress-relieved plates are open to suspicion owing to the failure of the results for these plates to satisfy the equilibrium conditions. There is very good agreement between Series I and the first two plates of Series II, which are the only ones comparable in the two series. Regarding the low elastic stress observed in the 2-in. plate of Series I, it is to be noted that this plate was given some 20% of weld metal, and developed an average shrinkage nearly double that of the 6 and 8-in. plates of this series. Most of the shrinkage in the 2-in. plate appears to have been plastic. The high values of local stress observed in the third and fourth plates of Series II are probably due, in part, to the greater energy applied when using the covered electrode and to the higher yield point of the deposited weld metal. All stresses remaining in the stress-relieved plates would, as mentioned previously, be expected to lie below the 1150° proportional limit of the material.

[3] Clark & White, *Trans. A.S.S.T.* 15, April 1929.

	Plate	Maximum Tension, Lb. per Sq. In.	Location	Maximum Comp., Lb. per Sq. In.	Location
Series I	2 in.	7,700	At weld	7,800	Center of plate
	4 in.	18,300	At weld	9,000	Center of plate
	6 in.	11,100	At weld	6,100	2 in. from weld
	8 in.	17,200	At weld	6,700	2 in. from weld
Series II (plain)	1-b	17,200	Just inside weld	7,600	3 in. from weld
	2-b	18,100	At weld	7,500	3 in. from weld
	1-c	26,800*	At weld	7,900	3 in. from weld
	2-c	36,600*	At weld	10,300	3 in. from weld
	1-b	1,800	Just inside weld	4,400	At weld
	2-b	1,500	Just inside weld	3,300	At weld
(relieved)	1-c	2,900	At weld	3,200	2 in. from weld
	2-c	4,500	At weld	1,800	2 in. from weld

* The yield point of metal deposited from the covered electrode used was from 50,000 to 55,000 lb. per sq. in.

Average Compressive Elastic Stress

The following table shows the average unit compressive stresses in the central portions of the plates, deduced from the average elastic recoveries. Stress-relieved plates are omitted.

	Plate	Average Compressive Stress, Lb. per Sq. In.
Series I	2 in.	7900
	4 in.	5800
	6 in.	5000
	8 in.	4900
Series II (plain)	1-b	4900
	2-b	5600
	1-c	6600
	2-c	7100

The figures for Series I appear to indicate that the average compressive stress decreases with a decrease in the percentage of weld metal applied. In the results for Series II, it is not justifiable to base any definite statements on the comparisons of the figures, since for any comparison there are only two plates in a group. While every precaution was taken to eliminate or minimize variables other than those involved in the welding treatment, deformations of the plates are so complex that, for any given treatment, it would be necessary to analyze a considerable number of specimens in order to obtain acceptable average values of shrinkages and recoveries for that treatment. It will be noted, however, that in Series II the plates to which the weld metal was applied in a single pass show a smaller average compressive stress than that observed in the plates welded in two passes. It might also be mentioned that in the diagrams of Fig. 6, the two former plates show less concentration of tension stress toward the root of the weld than do the two latter plates. As between bare and covered electrode, the former gave the smaller values of average compressive stress.

Additional Results

In addition to the investigation of the two series of specimens described above, some further measurements have been made on plates to which the weld bead was

applied continuously, and along one grooved edge only.[4] The plates were 9 in. square by 5/8 in. thick and were stress-relieved before welding, in order to reduce rolling stresses to a minimum. One plate was sawed into strips parallel to the weld and another was sawed at right angles to the weld. Plastic deformations and elastic stresses parallel to the weld showed close agreement with the results of the first two series, in the region adjacent to the weld, in so far as these very dissimilar plates could be compared. Substantial values of both deformation and stress were observed in the direction at right angles to the weld, the maximum stress near the weld being of the order of one-half of that parallel to the weld. Detailed results for these two plates are not included here, as this series is not comparable with the first two.

In conclusion, this paper is presented as a summary of the results obtained so far in this investigation. It is hoped that further information along similar lines will be made available by other experimenters. As already pointed out, it will be necessary to have the results from a considerable number of specimens of any one type, before acceptable average values may be taken for comparison.

[4] By C. Craig, Mech. Engr. (McGill), 1934.

Discussion of Alternating-Current Arc-Welding Papers*

By C. J. HOLSLAG†

IN EUROPE the open-circuit voltage necessary for alternating-current arc welding is standardized at 70 volts but they have not discovered the advantages of "fluid fusion" "hot arc" welding and have not met the necessity for higher voltages in deep, nearly parallel vees and for cutting and the opposite high-voltage requirements for aluminum, stainless, monel, etc. In other words the voltage for alternating-current arc welding lies between 70 and 110, and I would like to call attention to the fact that the Alternarc, the original transformer welder, which has had over twenty years development, has a choice of voltages with taps on the main coil, 70, 80, 90, 100, 110, so that any welding requirement can be met. Similarly there was quite a discussion over whether the reactor control should be of the movable core or the tapped type, the disadvantage of the movable core being its mechanical instability due to a very strong alternating torque at heavy currents, and the tap type being the rougher current gradation allowable. In our machine, we have both tap reactor and movable external core; that is, the core is not moved in the coil of the reactor nor is the reactor moved in any way. Separate laminated pieces which never touch the reactor itself are used to regulate the current. This, in combination with five current taps and five voltage taps, gives independent current and voltage control which is necessary to meet all arc-welding conditions. In regard to the low-voltage magnetic switch or safety device, Mr. Candy states you have the choice of push button immediate control subject to liability of the operator holding on to the button or a delayed timed magnetic switch. I think it is only fair to publish the fact that our contactor device has no buttons or switches, action is immediate and never at any time is the voltage above 40 short circuited, open circuited or in welding. This steady voltage of 40 is also very useful with automatic welding where the arc voltage is used to control the speed. If the open-circuit voltage was 110, the feed motor due to the high voltage would gain such an inertia momentum it would be hard to back it up, but with the open circuit at 40, which is also the arc voltage, the feed is steady. The open-circuit down-feed is the same as the welding voltage down-feed and the start of the arc does not have to be "assisted" manually.

It is true for very light welding A.C. is not as good for thin work and small currents as is D.C. and while the frequency oscillator assists in this direction on the light current, it is absolutely of no use whatsoever, say, above 90 amperes. The way we accomplish this for light currents is to superimpose D.C. on the A.C. by means of a rectifier which, of course, is a special form of transformer. An interesting phenomena is that pulsating D.C. requires the same reactance values to hold the arc as A.C. and that pulsating D.C. with sufficient reactance to hold the arc becomes A.C. due to the magnetic discharge.

Mr. Candy spoke of a reactance in the welding leads; of course, this is true. We recommend taping the leads together as far as does not hinder the welding facilities but we would also like to point out that the taps on our reactor allow for compensation of any combination of welding leads even when lying over iron plates because a lower reactance tap can be chosen to meet such conditions. It then makes no difference whether part of the reactance is in the leads and the remainder in the reactor or if it is all in the reactor. It is quite common in Europe to have a transformer at a fixed voltage, say 75, with several reactors adjustable by each operator independently of the other, that is, adjustable for current. The trouble with this system is there is no voltage adjustment ordinarily but we would like to point out that we furnish a transformer reactor control which can be used to boost or subtract from the "Mother" transformer and thus get both current and voltage adjustment. For instance, with a 20-volt booster transformer and a 90-volt "Mother" transformer, all voltages from 70 to 110 can be obtained with every possible current variation also. We make the same type of apparatus, incidentally, for these D.C. 60–65-volt multiple-operator sets, namely, a booster which will give a voltage range of 50 for very low, fine work to 90 for, say, aluminum welding. This booster (differential) control makes possible the so-called multiple operator sets to have the same advantages of independent voltage and current control as is now making the single operator sets preferable for such work as requires wide range of adjustment.

Mention is made of power factor and phase unbalance and, while these seem to be of minor importance when considering the better welding deposits possible with alternating current, yet I cannot help but point out that lighting load seems to divide itself very well among the phases even in chunks of 50 to 75 kw. as I have noticed in many plants. It would be perfectly simple to make a 3-phase lamp but diversity factor precludes the

(*Continued on page 34*)

* Presented at Fall Meeting A. W. S., October 1934.
† Electric Arc Cutting & Welding Company.

Brazing with Silver Solders*

By ROBERT H. LEACH†

ALTHOUGH it is possible to produce silver alloys which melt at temperatures below 1000° F. the term "silver solder" is usually applied to brazing alloys which require a red heat to melt them. Silver can be alloyed with copper, zinc, tin and cadmium or combinations of these metals in widely varying proportions to produce malleable and ductile alloys having a melting range considerably below the temperatures required for the use of base metal brazing solders, such as brass and spelter solders, nickel silver solders and other alloys generally classed as bronze welding rods. Nickel and manganese can also be used in certain proportions with silver and other base metals and the melting points will be within the range of silver solders in common use. It is evident, therefore, that an infinitely large number of binary, ternary or quaternary alloys can be made which would have melting points sufficiently low to allow their use for brazing purposes and it would be of great assistance to engineers responsible for specification of materials if it could be determined that a relatively few compositions would meet the ordinary industrial requirements.

Silver solders containing varying percentages of silver, copper, zinc, and in some cases tin and cadmium, have been used for many years. Many of the old solder formulae specified definite proportions of silver and brass. The use of different grades of brass resulted in a large number of alloys, many of which only varied slightly in actual percentage of the various metals, but at the same time if a certain composition had been used by a company for several years, and had been found satisfactory, there was some hesitancy in making any change even although it might involve only a difference of 1 or 2% in the copper or zinc content.

As silver solders were being extensively used in different industries the A. S. T. M. undertook the investigation of silver solders with a view of establishing, if possible, a limited number of standard compositions which would meet the ordinary requirements. A committee was appointed in 1926 and tentative standards covering eight grades of silver solders were issued in 1928 and adopted in amended form as standard in 1929. These specifications are given the A. S. T. M. designation B73-29 and the percentage of silver runs from 10% in the lowest grade to 80% in the highest grade. These alloys have high tensile strength and produce malleable castings which can be drawn into various sizes of wire and rolled into sheets of different thicknesses, thus allowing the solders to be supplied in the most convenient form for any particular class of work.

In general the addition of silver to copper-zinc alloys lowers the melting point and it is, therefore, possible to produce a series of ternary alloys which will flow freely at temperatures ranging from 1250 to 1600° F.

Figure 1 is a liquidus diagram of the silver-copper-zinc alloys which is based upon a large number of cooling curves made in the Research Laboratory of Handy & Harman, Bridgeport, Conn. The liquidus points were determined because from a practical point of view it is the liquidus or flow points of any alloy which is of more importance than the solidus or melting point when it is used for brazing purposes. Except in those cases where eutectic compositions may be used, such as the silver-copper eutectic which contains approximately 72% silver and 28% copper which melts at 1435° F., there is a melting range between the solidus or melting point and the liquidus or flow point. This range will vary and the fluidity of the solder between these points will depend upon the proportion that solidifies at the liquidus temperature. The solidus point is important when second soldering operations are to be made on the same article, and also when the joint may be subjected to elevated temperatures in use. It is, therefore, advisable to know both the melting and flow points of the particular alloy which is used for soldering.

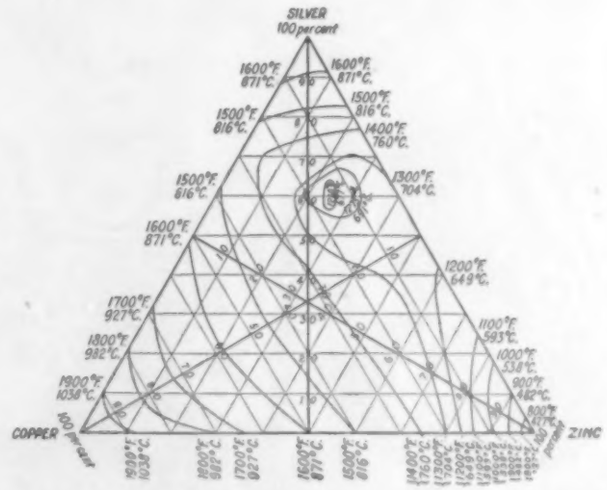


Fig. 1—Liquidus Diagram of Silver-Copper-Zinc Alloys Based upon a Large Number of Cooling Curves Made in Research Laboratory of Handy & Harman

("Silver Solders" by R. H. Leach. Proceedings of the A. S. T. M., Vol. 30, Part II, 1930.)

Those solders containing lower percentages of silver are less expensive but have higher flow points and, therefore, do not give a wide factor of safety when used for brazing metals or alloys that may be seriously damaged at the higher temperatures required for their use. In such cases the use of silver solders having higher percentages of silver and lower flow points are to be preferred. When joints of high ductility and malleability are required, as, for example, copper rods that are to be drawn into small diameter wire, silver solders containing from 70 to 80% silver and small percentages of zinc have proved most satisfactory. Also the resistance to certain types of corrosion may justify the use of solders of high silver content. As a rule industrial users have found that solders within the range of 40 to 50% silver

* Paper to be presented at the Fall Meeting, A. W. S., October 1–5, 1934.
† Manager, Handy & Harman.

will meet their needs when the use of the lower grades would involve too much risk of overheating the parts to be joined.

The rapid increase, however, during the past few years in the use of different types of welding and brazing processes has brought the question of the most suitable type of alloy for a given purpose more prominently than ever before those interested in joining metals. Great advancements have been made in equipment designed for supplying the heat necessary for welding and brazing, new alloys developed and the scientific side of the art of joining metals has enlisted the interest of engineers in the search for fundamental information that will give them a sound basis upon which to base their recommendations.

The particular places in which silver solders are more suitable than other types of alloys can only be determined by the consideration of many factors, such as physical properties, corrosion resistance, relative ease of application because of low melting point, strength of joint and cost, with the recognition that experience has shown that the free flowing properties of silver solders permit closely fitted joints and the use of a correspondingly small amount of solder.

At the June meeting of the A. S. T. M. in 1930 I presented a paper on silver solders which has been available in pamphlet form since that date. As there have been no radical changes in the art of brazing silver solders it has been impossible to avoid some repetition of previously published data.

Physical Properties

The user of silver solders is primarily interested in the physical properties of joints made with these solders, but at the same time the general characteristics of the solders themselves would seem sufficiently important for a brief description.

Any alloy which is satisfactory for brazing purposes must flow freely at a temperature below the melting point of the metals or alloys which are to be joined. In the introductory paragraphs on silver-copper-zinc alloys, general reference was made to the relatively low flow points of silver solders as compared with other brazing alloys. Further reference to the liquidus diagram of the silver–copper–zinc system in Fig. 1 shows that the use of high percentages of zinc proportionately reduces the flow points, but there is a practical limitation to the amount of zinc which can be used because of the brittleness of the resulting alloy. With the silver content as low as 10% the percentage of zinc should not exceed 40% for the production of malleable and ductile alloys and the flow point will be approximately 1600° F. With 65% silver and 25% zinc the flow point drops to approximately 1250° F. An alloy of this composition is malleable but in actual practice it is not customary to use over 15% zinc which raises the flow point to approximately 1300° F. A composition which is widely used for industrial purposes contains 50% silver, 34% copper and 16% zinc and flows freely at 1435° F.

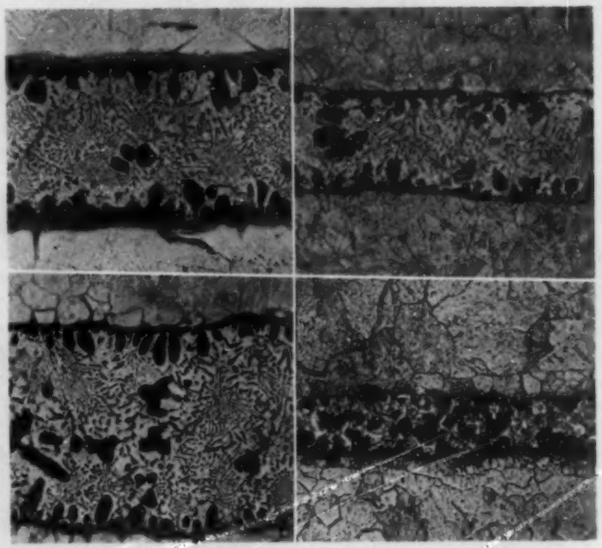
Table 1 gives the melting and flow points of the silver solders in A. S. T. M. specifications.

Table 1

Grade No.	Composition Silver, %	Copper, %	Zinc, %	Cadmium, %	Melting Point, ° F.	Melting Point, ° C.	Flow Point, ° F.	Flow Point, ° C.	Color
1	10	52	38		1510	820	1600	870	Yellow
2	20	45	35		1430	775	1500	815	Yellow
3	20	45	30	5	1430	775	1500	815	Yellow
4	45	30	25		1250	675	1370	745	Nearly white
5	50	34	16		1280	695	1425	775	Nearly white
6	65	20	15		1280	695	1325	720	White
7	70	20	10		1335	725	1390	755	White
8	80	16	4		1360	740	1460	795	White

(a) Brass Soldered with 50% Silver, 34% Copper, 16% Zinc. Etched with $NH_4OH + H_2O_2$

(b) Nickel Silver Soldered with 50% Silver, 34% Copper, 16% Zinc. Etched with Acid Ferric Chloride



(c) Copper Soldered with 60% Silver, 25% Copper, 15% Zinc. Etched with $NH_4OH + H_2O_2$

(d) Stainless Steel Soldered with 40% Silver, 36% Copper, 28% Zinc. Etched with Chrome Regia

Fig. 2—Photomicrographs of Various Silver-Solder Joints (× 500)

Effect of Other Metals

The addition of cadmium to solders containing high percentages of zinc increases their malleability and ductility but the effect on the flow point depends upon the composition of the solder. In those silver solders containing lower percentages of silver it is possible to use a combined zinc and cadmium content sufficiently large to lower appreciably the flow point and still produce a malleable alloy. Table 2 gives a number of compositions which illustrate the effect of cadmium on the thermal points.

Table 2—Effect of Cadmium on Thermal Points of Silver Solders

Chemical Composition Silver, %	Copper, %	Zinc, %	Cadmium, %	Melting Point, ° F.	Flow Point, ° F.
65.0	20.0	15.0	..	1280	1325
65.0	20.0	5.0	10.0	1320	1370
30.0	35.0	17.0	18.0	1160	1380
20.0	45.0	35.0	..	1400	1510
20.0	45.0	30.0	5.0	1400	1485
50.0	15.5	16.5	18.0	1160	1175

Tin also has the effect of lowering the flow point but, if used in considerable amount, is likely to cause brittleness.

Strength, Malleability and Ductility

Any unaltered solder which may remain in the joint will have the physical properties of a very thin casting

regardless of the form in which the solder may have been used. Nearly all silver solders which have proved satisfactory can be cast into wire bars or ingots which will stand at least 50% reduction in cold working without any signs of failure. In order to obtain some idea of the strength of silver solders in cast form a series of tests were made on bars having a cross section 0.100 to 0.300 which were cast in iron molds. The results which are given in Table 3 show tensile strengths running from 40,000 to 60,000 lb./sq. in. with an elongation from approximately 6 to 34% in 2 in. The difficulty in getting sound chilled castings in these dimensions causes considerable variation particularly in the elongation, but it is believed that they give a general guide as to the strength of these alloys in cast form.

Table 3—Physical Properties and Electrical Conductivity of Silver Solders

Chemical Composition					Physical Properties			Electrical Conductivity	
Silver, Per Cent	Copper, Per Cent	Zinc, Per Cent	Cadmium, Per Cent	Nickel, Per Cent	Specific Gravity, as Cast	Tensile Strength, Lb. per Sq. In.	Elongation in 2" In., Per Cent	Conductivity (Copper, 100 Per Cent)	Resistance, Microhms per cu. cm.
9.0	51.0	40.0	...	...	8.55	48,800	16.0	20.5	8.33
20.0	45.0	30.0	5.0	...	8.80	53,000	12.0	24.4	7.69
25.0	52.5	22.5	...	...	8.94	...	..	24.4	7.69
30.0	38.0	32.0	...	...	8.86	...	..	24.4	7.69
40.0	30.0	28.0	...	2.0	9.04	...	..	16.8	10.17
40.0	36.0	24.0	...	...	9.11	57,800	6.2	19.7	8.65
45.0	30.0	25.0	...	...	9.15	...	..	19.0	8.97
46.0	38.5	15.5	...	...	...	49,900	9.0	...	...
47.0	29.0	24.0	...	...	...	58,500	16.0	...	...
50.0	28.0	22.0	...	...	9.22	...	..	19.7	8.65
50.0	32.5	17.5	...	...	...	55,500	9.0	...	...
50.0	34.0	16.0	...	...	...	...	..	24.1	7.04
60.0	25.0	15.0	...	...	9.52	64,300	7.7	20.5	8.33
65.0	20.0	15.0	...	...	9.60	64,800	34.0	21.3	8.01
70.0	30.0	..	...	...	...	57,500	25.0	...	...
70.0	25.0	5.0	...	...	...	50,300	9.5	...	...
70.0	20.0	10.0	...	...	9.76	...	..	26.7	6.41
72.0	28.0	..	...	...	9.95	...	..	77.1	2.24
75.0	20.0	5.0	...	...	9.92	...	..	38.1	4.48
75.0	22.0	3.0	...	...	10.03	41,800	5.3	53.4	3.20
80.0	16.0	4.0	...	...	10.05	50,100	16.0	45.8	3.73
100.0	...	..	..	...	...	...	..	106.7	1.60
...	100.0	..	...	...	...	...	..	100.0	1.71

(Proceedings of the A. S. T. M., Vol. 30, 1930, Part II, "Silver Solders." R. H. Leach.)

Corrosion Resistance

Silver solders are resistant to the ordinary atmospheric corrosion. They are attacked by nitric acid and discolored by gases or products containing sulphur. Experience has shown that their corrosion resistance compares favorably with the various non-ferrous metals and alloys which have wide industrial use because of their corrosion-resistant properties. The high-grade solders particularly are used in the manufacture of chemical products and the silver-copper eutectic is often used as a silver solder where the presence of zinc in the alloy would be harmful.

Electrical Conductivity

The electrical conductivity of silver solders varies considerably with different compositions. In the silver-copper-zinc silver solders the percentage of zinc appears to have the greatest influence on reducing the electrical conductivity. Results of tests made on several alloys are given in Table 3 and are generally indicative of what may be expected. Where conductivity is important reference to the table shows that the higher grade solders with low melting points have comparatively high conductivity.

Specific Gravity

The specific gravity of some of these alloys is also given in Table 3 and will run from approximately 8½ to 10.

Methods of Using Silver Solders

The development of torches, furnaces and electrical devices gives a wide range of equipment which is suitable for supplying the heat necessary for joining metals with silver solders. Although the better types of air and gas torches are used to considerable extent, the oxyacetylene torch gives a much wider range of flexibility and quicker heating. The necessity for preheating the surfaces to be joined is greatly reduced and there is a great saving of time as well as the advantage of being able to control the type of flame. When torches are used for heating there are two methods in use. In the first method the procedure is to bring the temperature of the joint up to or slightly above the flow point of the solder and then apply the solder to the joint directly under the torch flame. When joints are made in this manner silver solders will flow for considerable distances and penetrate into narrow openings.

The other method more nearly approximates the procedure sometimes followed in bronze welding where the sections to be joined are not brought up to a temperature above the flow point of the solder and the superheat in the solder itself is depended upon to bring the joint to the proper temperature. With the oxyacetylene torch it is possible to supply heat to the joint so rapidly that the two methods to a casual observer may not be distinguishable and with the excellent equipment now obtainable a workman can soon acquire the necessary skill for applying the heat to any particular type of joint.

Thin strips or sheets of solder can be inserted between the surfaces to be joined before heating. In this method of making a joint with a torch flame the appearance of a thin line of molten solder along the outside edge is an indication that the proper temperature has been reached but it is important to see that clamps or supports are provided to hold the pieces firmly together.

Different types of furnaces are also used for heating. The parts are assembled with the solder either along or in the joint and the assembled unit placed in the furnace. In this type of heating the entire assembly has to be brought to a temperature above the flow point of the solder and the time required for heating will depend upon the temperature of the furnace, rate of heat input, size of the assembled part in relation to the furnace and the specific heat of the materials. As a rule it is more satisfactory to run a furnace at a temperature considerably above that necessary to flow the solder and thereby reduce the time in the furnace. This necessitates that the time must be determined empirically but experience has shown that, other conditions being equal, the best results will be obtained if the solder is brought to the flow point as quickly as possible. Rapid heating seems to be particularly helpful in those cases where finely granulated solders are spread along the joint. To illustrate this point some interesting tests were made in the following manner.

Two pieces of 14-gage metal were assembled on a carbon block and 300-mesh solder sprinkled along the joint. The end of a thermocouple was then attached to one of the pieces of metal and the block introduced into a closed type electric furnace having a hydrogen atmosphere. The temperature of the furnace was taken with another pyrometer. The silver solder used was known to flow at 1300° F. and the assembly was removed as soon as the metal reached this temperature. The results obtained by using three different furnace temperatures are shown in Table 4.

The atmosphere in a furnace used for brazing should

Table 4

Furnace Temperature, ° F.	Time Required to Bring Metal to 1300° F., Min.	Character of Joint
1400	10	Poor. Partly melted solder on surface.
1600	5	Better but not satisfactory.
1800	2½	Good joint—solder had flowed well.

be non-oxidizing. When the work involves the joining of a large number of pieces of uniform size if proper attention is given to control of the furnace temperature and atmosphere, furnace heating is efficient and will give uniform and satisfactory results.

There are different types of electric-resistance heating devices available by which the heat is applied directly to the joint. Thin sheets of silver solder can be inserted in the joint and the principal advantage over ordinary welding is the lower temperature required to flow the solder. Many different types of joints can be made with this method and by using silver solders exceptionally strong joints can be obtained at relatively low temperatures.

Proper control of the heat is an important factor in obtaining uniform and strong joints. Investigations have shown that the best silver soldered joints are obtained when there is some degree of diffusion between the solder and the metal. This diffusion is a time and temperature reaction and will vary with the type of metals being joined. With the majority of non-ferrous alloys microscopic examinations will show this diffusion. With steels and alloys which have melting points several hundred degrees above that of the solder it is more difficult to positively determine this point but the evidence obtained from the examination of a large number of specimens at high magnifications would seem to justify the statement that some degree of diffusion is present in all properly made silver solder joints. An article published in *Metals & Alloys* in November 1931 describes in more detail some work which was done in reference to the type of bond obtained with silver solders. Figure 2 shows some photomicrographs of silver solder joints.

Fluxes

Before discussing the action of different fluxes it should be emphasized that joints should be clean and well fitted. Surface scale, oxides and all grease and foreign matter of any description should be removed. The function of the flux is three-fold; it offers a protective coating which tends to prevent oxidation, dissolves any oxides which may form and assists in the free flowing of the solder.

The last-named function is important and it has been found advantageous in some cases to use flux in furnaces having a reducing atmosphere such as hydrogen where oxidation could not take place. Capillary attraction is the principal force causing solders to flow and as the flux flows ahead of the solder and is displaced by it, it seems reasonable to assume that a nascent metal surface is thereby provided if the proper flux is used. The term nascent may not be the correct one, but the thought which it is meant to convey is that for proper joining both the surface of the solder and the surface of the metal should be absolutely free of any oxide films or adsorbed gas films.

There are a number of good fluxes made by different manufacturers and the choice of flux depends largely upon individual preference.

Fluxes that fume badly are, of course, objectionable to the workman but the flux must be fluid and active at the temperature used for soldering.

Borax will dissolve the oxides of most of the metals and becomes a very thin fluid at a temperature of 1400° F. The water of crystallization in ordinary borax causes bubbling of the flux during the preliminary heating and this objection can be overcome by using the anhydrous form of borax.

Boric acid is commonly used in connection with borax and has the particular property of spreading over the surface at a low temperature and offers protection against oxidation. It does not dissolve oxides as readily as borax and mixtures of borax and boric acid becomes viscous at higher temperatures than borax alone. When joining metals having refractory oxides such as chromium, it is necessary to use special fluxes to remove them. Thin films of these oxides which cannot be seen will be quite sufficient to prevent good bonding. Fluxes containing either halogen or fluorine compounds are recommended in removing these oxides. Table 5 gives the results of some tests which were made to determine the solvent power of different salts which are used in making fluxes. These tests were made by taking known quantities of the oxides and fluxes and heating them in pure silver crucibles for a period of 10 min., at 1400° F.

Table 5—2 Grams of Oxide and 20 Grams of Flux Were Used in Each Test. Anhydrous Fluxes Were Used

	Weight of Oxide Dissolved in Grams							
Flux	ZnO	CdO	NiO	Al_2O_3	SnO_2	CuO	Fe_2O_3	Cr_2O_3
Borax	2.0	2.0	0.62	2.0	0.84	1.45	2.0	0.001
Boric Acid	0.56	0.84	0.02	None	None	None	None	None
Spec. No. 1	2.0	1.30	0.01	2.0	1.12	0.69	1.37	0.01
Spec. No. 2	2.0	2.0	0.02	2.0	0.94	1.06	2.0	0.01

One of the principal advantages in the use of silver solders is the strong joints which may be obtained at relatively low temperatures and it would seem logical, therefore, to use a flux which was fluid and active at these temperatures. If the joint is one that does not require the solder to flow for any appreciable distance a more viscous flux may not seriously affect the results.

It is advisable to protect both the surfaces along the joint and the solder with the flux. It is a practice in some plants to assume that sufficient flux will adhere to the solder to clean off any oxide but the objection to this is the formation of oxides on the surface of the joint while the heating is being done and the time spent in protecting joints with flux during the heating is justified. Some users will put flux along the joint but neglect to protect the solder because it requires an extra operation. It is a simple matter for the workman to dip the end of the solder into a small can of flux paste, and this added precaution against troubles from oxidation is advisable. One of the objections which is raised to spreading the flux along the joints is that the solder will flow over the surface at the sides of the joint where it is not needed. If the pieces to be joined are jigged so that the workman is free to apply the solder properly he will only use a sufficient amount to fill the joint and there should be no appreciable waste of solder from this source.

The use of flux in a paste form or a hot saturated solution is convenient because it can be brushed along the joint thus insuring a more uniform protection and less likelihood of bare spots which will oxidize during the period of heating. In the final analysis the choice of flux and the best method of applying it will depend upon the metals to be joined, method used in heating and the type of joint. It cannot be too strongly emphasized that clean joints and careful attention to the selection

and use of a suitable flux are essential to the production of sound joints.

Special Solders

The satisfactory results which have been obtained for many years with the ternary alloys enumerated in the first part of this paper at least establishes a standard to which other silver alloys can be compared. With the increasing use of different types of corrosion-resistant base metal alloys and stainless steels there is an increasing interest in determining whether it would not be possible to produce more satisfactory alloys.

The substitution of either nickel or manganese or both for part of the copper and zinc in standard silver solders produces a series of alloys which may be more satisfactory in resisting certain types of corrosion. Some of these alloys are not as free flowing as the better known silver solders, but satisfactory joints can be made with them at approximately the same temperatures. One of the fields where these alloys might find more extensive use is in brazing stainless steel.

There is a diversity of opinion in regard to the advantages of using silver solders with stainless steels. Strong joints can be made with a wide range of compositions, but the temperatures required for the use of silver solders comes within what has generally been accepted as the critical range which causes carbide precipitation and that is probably one of the reasons why silver solders have not been more widely used.

It is possible to produce a malleable and ductile silver solder containing sufficient combined zinc and cadmium to bring their flow points below 1200° F. If we consider that carbide precipitation is a time and temperature reaction it would seem as though the use of a silver solder with such a low flow point might overcome most of this difficulty if the heating is done quickly.

Frequent inquiry is made for a silver solder which will flow at temperatures below 1000° F. and produce strong joints. It is possible to alloy silver with different percentages of cadmium, zinc and tin and obtain alloys with thermal points ranging from the melting points of soft solders to those of standard silver solders. In many cases the resulting alloys are brittle and cannot be fabricated and when used in granular form give joints that are not satisfactory. Other combinations are malleable and have exceptionally long melting ranges with the solidus approaching the soft solder and, therefore, are of no particular commercial value. There has been, however, a limited use of compositions containing low percentages of silver in those places where a solder somewhat stronger than soft solders is satisfactory. Table 6 gives a few of these compositions. These alloys do not have the physical properties of standard silver solders and should only be used after a thorough trial had proved that they would not meet the requirements.

The ternary silver-copper-phosphorus eutectic melts at 1190° F. and by changing the composition slightly it is possible to produce alloys which can be drawn into various sizes of wire and rolled into thin sheets. These alloys will make strong joints on copper, brass, nickel, silver and other non-ferrous alloys. They are not to be recommended for use with iron or steel because of the formation of phosphide of iron.

These alloys are self fluxing on copper joints and require only a small amount of flux when used with brass and other alloys.

Summary

Silver solders can be used on practically all ferrous and non-ferrous metals and alloys having melting points above 1300° F.

Table 6—Low-Melting Silver Alloys

Chemical Composition, Per Cent					Melting Point, Deg. Fahr.	Flow Point, Deg. Fahr.	Cold Working Properties
Silver	Cadmium	Zinc	Tin	Copper			
5.0	78.4	16.6	..	..	480	600	50-per-cent reduction
15.0	70.0	15.0	..	..	520	750	50-per-cent reduction
20.0	66.0	14.0	..	..	640	850	Brittle
20.0	30.0	..	50.0	..	420	780	1/2 in. to 0.030 in. without annealing
40.0	..	6.0	40.0	14.0	690	800	Brittle
30.0	..	30.0	40.0	..	860	1060	50-per-cent reduction, but cracks on edge
20.0	..	50.0	30.0	..	650	970	50-per-cent reduction, but cracks on edge

("Silver Solders," R. H. Leach, Proceedings of the A. S. T. M., Vol 30, Part II, 1930.)

They can be obtained in granular or filed form, in sheets and strips from a few thousandths to any heavier gage that may be required and in wire in all diameters, thus making it possible to supply them in the form required for different sizes and types of joints.

Their free-flowing properties and relatively low temperatures allow engineers to design joints with small clearances which will have great strength and ductility and will stand severe shocks and bending stresses.

A wide factor of safety is provided against damage to metals and alloys from overheating the parts to be joined because of the low temperatures required to flow silver solders. The time required to make the joint is correspondingly shorter and the labor cost is proportionately reduced.

Malleable butt and seam joints can be made which will stand severe cold work such as hammering, rolling, drawing and forming into different shapes. Scarf and lap joints on sheet metal and properly fitted pipe joints show high strength, often exceeding that of the metals themselves and failure will take place outside the joint.

The corrosion resistance of silver solders is good and compares favorably with metals and alloys used particularly for their corrosion-resistant properties. Some compositions are more resistant than others to specific corrosive conditions and the galvanic attack which is affected by the metals joined necessitates that careful tests should be run in order to determine the most suitable solder.

Although the cost of silver solders per unit of weight is greater than that of base metal alloys this does not necessarily mean that the cost of making joints with silver solders is proportionately higher when all factors are taken into consideration. The strongest joints are obtained when a minimum amount of solder is used and by proper design of joint the actual weight of silver solder is so much less than that required for equivalent strength with base metal alloys that in some cases even the difference in first cost is negligible. In addition to this the lower temperature required, the saving in time and fewer rejections will, in many cases, offset the higher initial cost of the solder and show an actual economy over the use of base metal solders.

Acknowledgment

The author desires to express his appreciation for the assistance of his associates in the preparation of this paper and to Handy & Harman for their courtesy in allowing the publication of this data.

Fabricating Stainless Clad Steel

By W. B. KEELOR†

What IngAclad Is

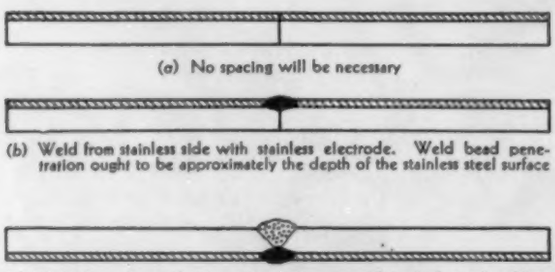
STAINLESS clad steel was developed to retain the corrosion resisting advantages of solid stainless steel, but at a reduced cost. It is a ply material having a thin surface of true stainless steel on a foundation of soft or mild steel.

It is evident that if a sheet or plate has but a thin surface of the costly stainless steel, and the bulk of that sheet or plate is ordinary steel, the cost of the stainless clad product will be much lower than if the material were entirely composed of solid stainless steel. It is on this basis that IngAclad has found acceptance in so many applications where the corrosion resistance of stainless steel was desired, but where the economy of the clad steel dictated its use.

Stainless clad steel may be produced with a variety of stainless steel surfaces and a stainless cladding, varying from a very thin layer to a thickness comprising 30% or more of the total sheet or plate thickness. It has been found, however, that the 18–8 stainless steel cladding, comprising 20% of the total sheet or plate thickness satisfies most commercial requirements.

The physical properties of stainless clad steel are a combination of the physical properties of the two metals—mild steel and stainless steel—which form the combined sheet or plate. Thus the tensile strength of the stainless surface is identical with the tensile strength of a similar sheet or plate of solid stainless steel. Likewise the strength of the mild steel is not affected by being in combination in the clad material. The user is assured that the tensile strength of the clad material is as high or higher than the combined strength of the two materials.

Standard Butt Welds of IngAclad Are Preferable and Less Costly Than Lap Welds



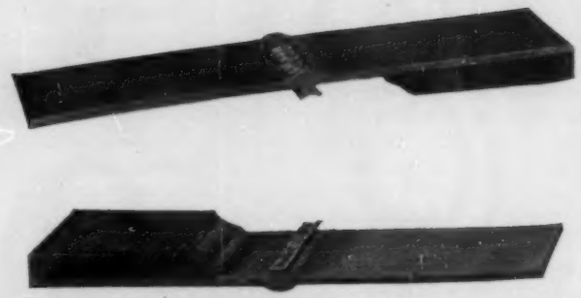
(a) No spacing will be necessary

(b) Weld from stainless side with stainless electrode. Weld bead penetration ought to be approximately the depth of the stainless steel surface

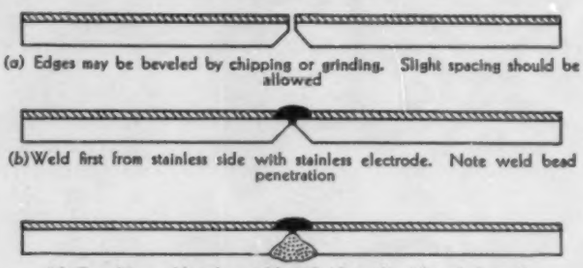
(c) Weld from the steel side with stainless or mild steel electrode. Here the weld bead penetration is approximately the thickness of mild steel

Fig. 1—Recommended Procedure for Welding Stainless Clad Steel No. 10 Gage and Thinner

† Ingersoll Steel and Disc Company



Acid Eats Away the Mild Steel but the Stainless Steel Is Unaffected—Both on the Surface and in the Weld



(a) Edges may be beveled by chipping or grinding. Slight spacing should be allowed

(b) Weld first from stainless side with stainless electrode. Note weld bead penetration

(c) Complete welding from mild steel side with mild steel electrode

Fig. 2—Recommended Procedure for Welding Stainless Clad Steel No. 10 Gage to 3/8 In.

It may be used wherever the use of a corrosion resistant metal is desirable or practical, within certain limitations. In many applications, such as tank work, pressure vessels, etc., it has definitely established itself as the most economical form of stainless material available, due to the initial economy of the clad steel.

It should not be used for heat applications in which the mild steel side would be adversely affected due to oxidizing and other factors which may affect the mild steel at elevated temperatures. Because of this, the heat limit for stainless clad steel application is about 800° Fahr.

In designing any vessel where the vessel, its fittings or its parts, are to be in contact with liquids, it is the best practice to have all fittings and parts of the same material as the vessel itself. This prevents any electrolytic or galvanic action which would corrode the different metals or alloys employed.

Metal Arc Welding

When welding the stainless side of IngAclad by the metal arc method, the electrode should be positive and the work negative (reversed polarity). Electrodes should be of the proper analysis for the cladding being welded. In the case of the 18 chrome 8 nickel cladding, it has been found that the 24 chrome 12 nickel electrode offers a corrosion resistance equal or superior to that of the stainless surface. However, jobs have been successfully welded using the 18 chrome 8 nickel electrode with a carbon content not to exceed 0.08%. There is no

(a) Prepare joint in this manner

(b) Weld with stainless electrode in bottom of groove, complete with shielded arc mild steel electrode in multiple beads

(c) Chip with pneumatic hammer or grind with narrow rubber bonded wheel

(d) Complete with stainless steel weld deposit

Fig. 3—Recommended Procedure for Preparation of 1/4 In. and Heavier Plate

(a) Space 1/16 in. to 1/8 in. depending upon thickness

(b) Weld in the bottom groove from steel side with stainless electrode. No backing strips will be necessary if proper gap is allowed

(c) Complete with shielded arc, mild steel electrode, then chip or grind stainless side

(d) Complete welding with stainless electrode

Fig. 4—Recommended Procedure for Butt Welding Plates 1/4 In. and Heavier when No Plate Planing Equipment Is Available. Chip Each Side to 30–45° Angle with Pneumatic Hammer

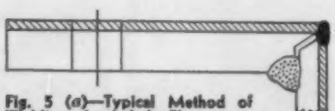


Fig. 5 (a)—Typical Method of Welding IngAclad Flange on End of Pipe

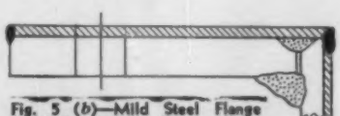


Fig. 5 (b)—Mild Steel Flange Welded to Clad Sheet; Solid Stainless Steel Ring Welded to Face of the Flange after Machining

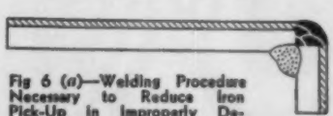


Fig 6 (a)—Welding Procedure Necessary to Reduce Iron Pick-Up in Improperly Designed Corner. Note Multiple Beads of Stainless Weld Necessary at Corner

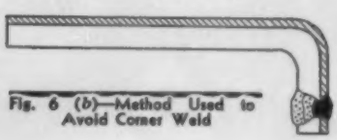
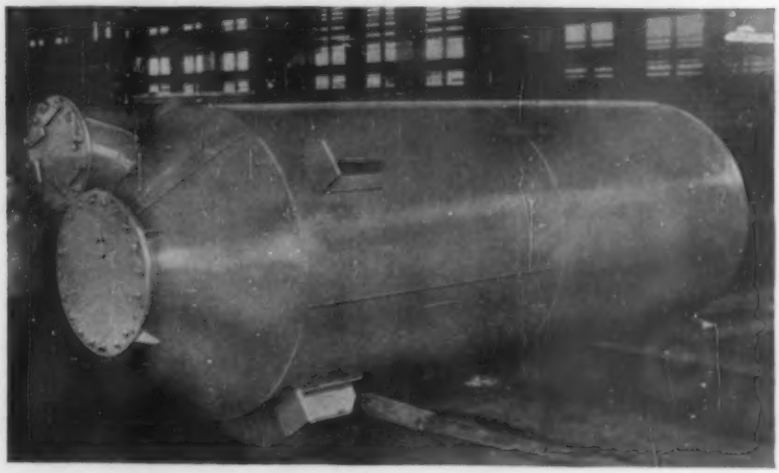


Fig. 6 (b)—Method Used to Avoid Corner Weld



More and More the Chemical Industry Turns to Stainless Clad Steel for Anti-Corrosion and Economy. These Forced Circulation Evaporators, with Heating Elements and Fittings All of Clad Steel Are Serving an Eastern Manufacturing Chemist

All Welded Pressure Vessels Are More Economical If Built of IngAclad. One of the Country's Great Producers of Soap Products Installed This Autoclave—26 Feet Long, 6 Feet Diameter. Tested and Approved at 250 Lb. per Sq. In. Pressure. Shell 13/16 and Heads 1-in. Clad Plate

Fig. 7—Welding Procedure for Right Angle Intersections in Construction of Clad Steel Tanks. No Porosity Results in Welding Over Stainless Ply When Using High-Grade Shielded Arc Mild Steel Electrodes. Note Welds (a) and (b)

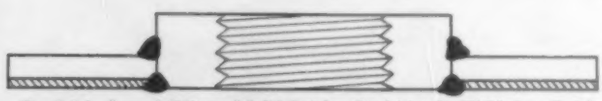


Fig. 8 (a)—Tapped Fittings of Solid Stainless Steel May Be Welded to Stainless Clad Sheets or Plates as Shown

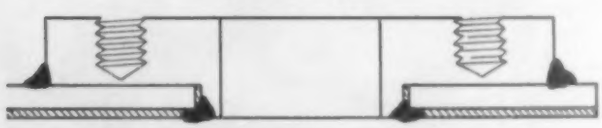
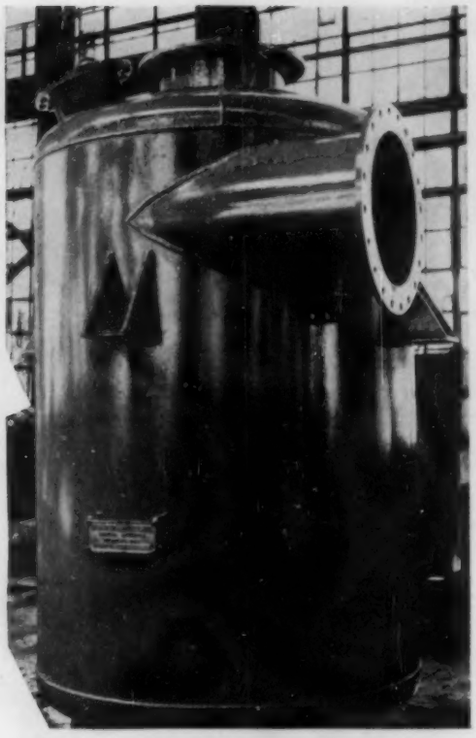


Fig. 8 (b)—Stainless Steel Flange Fitting Welded to a Stainless Clad Unit



This Giant Centrifugal Separator Illustrates the Ideal Combination of Solid Stainless and Stainless Clad Steels. The Inner Elements Subject to Corrosive Attack on Both Sides Were Made of Solid Stainless Steel. The Outer Shell Here Shown Is of All Welded Stainless Clad Steel

record of a failure of a weld where either the 24–12 or 18–8 electrode has been used, if the proper procedure has been carried out. When welding other analyses of cladding, it is advisable that the electrode have a higher alloy content than that of the material being welded.

Electrodes should be of the flux-coated type, having a carbon-free coating as well as an extremely low-carbon base metal. Such electrodes are furnished by a number of manufacturers.

The amperage used for welding the stainless steel surface should not be excessive. Too high an amperage will cause overheating of sheet in weld area, also overheating of welding electrode. Extremely low amperage will cause slag inclusions and lack of fusion. Trial welds should be made before beginning a job because prevailing conditions, analysis, type of coating, amount of coating, length of electrode, etc., have definite bearing on the amperage required for each diameter of electrode.

When ordering stainless steel electrodes it is not wise to specify length because the amount of coating and type of coating used on such electrodes will have a definite bearing upon the proper length to use. The larger diameter electrodes are ordinarily furnished in greater lengths than the small diameters. Most electrode manufacturers will furnish the proper length of electrodes for each given diameter.

The required electrode diameter for various sheet and plate thickness is approximately as follows:

$^1/_{16}$ in. for sheets under No. 14 gage
$^3/_{32}$ in. for No. 16 gage to $^3/_{16}$ in.
$^1/_8$ in. for $^3/_{16}$ in. to $^1/_2$ in.
$^5/_{32}$ in. for $^1/_2$ in. to 1 in.

When welding the lighter gages it is wise to use chill bars wherever possible, since it is necessary that the weld and adjacent metal cool quickly. On heavy material this is not necessary because the mild steel backing acts effectively as a chill.

Since mild steel normally comprises 80% of the total thickness, the heat is dissipated more rapidly than would be the case in like gages of solid stainless steel sheets or plates, due to the relatively higher heat conductivity of mild steel. This natural advantage of stainless clad steel combined with the low-carbon content (0.12% or less) of the stainless surface eliminates, in practically all cases, the necessity for heat treatment after welding.

No Peening Required

It is not at all necessary to peen stainless welds. No slag inclusions or porosity of any kind will be encountered if proper electrodes are employed with the proper welding technique.

No porosity results from welding over steel with stainless electrode or over stainless steel with a high-grade shielded arc mild steel electrode. Note procedures employed in Figs. 4*b* and 7*a*.

Welding of Mild Steel Side

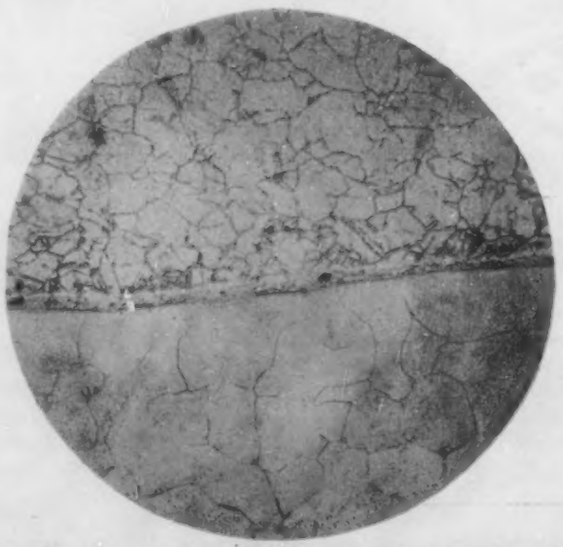
In welding the mild steel side of the plate it is necessary to weld with multiple beads to avoid overheating of the stainless surface. In practically all cases, except where the most severe corrosion conditions exist, it is not necessary to heat treat after welding if the proper care is taken in welding. It is best to use a high quality mild steel shielded arc electrode for welding the mild steel side.

Vertical Welding

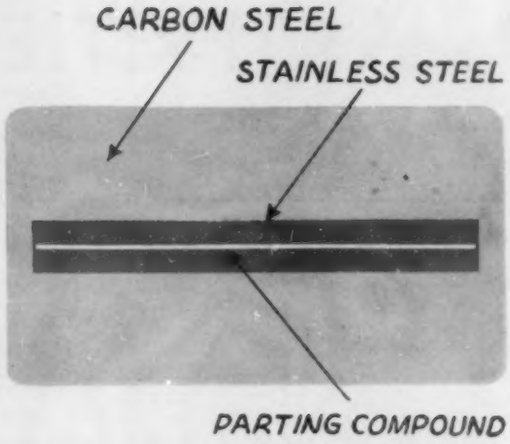
Clad steel may be welded in the vertical position with no great difficulty. Sheet stock will usually have to be welded by starting at the top and welding downward, while heavier plates may be welded starting at the bottom and welding upward. The electrode chosen for such welding will definitely affect the procedure required, however.

Design and Preparation

Design and preparation for welding have much to do with the cost and also with the quality of weld deposits. By employing proper designs it is possible to reduce welding labor materially, and also the amount of stainless steel electrode may be held to a minimum. Note comparison—Figs. 6*a* and 6*b*.



The Photomicrograph Discloses the Perfect Bond That Exists between the Stainless Surface and the Mild Steel Ply of IngAclad. Magnified 200 Diam. Shows Actual Fusion at the Weld



The Welded-in-the-Ingot Method of Producing IngAclad Is Here Illustrated Diagrammatically. Note the Two Stainless Plates in the Ingot with Ground Surfaces Face to Face, and Sealed to Prevent Admission of Gases, Atmospheres or Molten Steel

In all cases joints should be designed so that iron pick-up will be prevented. Where steel is exposed as in the case of lap and corner welds, it is best to apply a stainless weld in several layers (see Fig. 6*a*). This condition may be eliminated in most cases (see Fig. 6*b*).

The Production of IngAclad

The process of making IngAclad consists essentially of two major operations: first, the production of stainless steel plates, and second, the process of making the ply-steel. The stainless steel, usually of the type designated as 18–8, is made up of a major portion of virgin metals poured into ingot molds and rolled into plates. After rolling, the plates are cleaned and ground and cut into inserts which are used in making clad-steel.

After proper preparation one face of each stainless plate is coated with an insulating material. The coated plates are then placed face to face and the four edges are sealed by arc welding. These two plates, thus joined, are known as an insert.

An insert of stainless steel as described above is then placed in a mold. Mild steel of a special analysis is then poured in the mold, completely covering the stainless steel insert, producing a composite ingot. The ingots so produced are rolled into sheets or plates of desired gage. After finish rolling all sheets are annealed to produce the austenitic structure desired. The four edges are then sheared back to the point where the stainless steel begins, thus producing two stainless clad sheets from each ingot.

All clad steel sheets are then pickled and passivated to bring out the maximum corrosion resisting qualities of the stainless steel.

It is apparent that with this cast-in-the-ingot method the stainless steel surface of the clad sheet or plate is not subject to roll marks, scaling or oxidation because the stainless surfaces are completely surrounded by an envelope of soft steel during the heating, rolling and annealing operations.

This patented method of producing IngAclad from a composite ingot insures a bond between the stainless surface and the mild steel.

CURRENT WELDING LITERATURE

Apartment Houses. Welding Used Extensively in Tall Apartment House in Poland, S. Bryla. Eng. News-Rec. (Oct. 25, 1934), vol. 113, no. 17, pp. 524–525. Method of welding steel frame of 17-story Prudential House in Warsaw, Poland.

Automobile Body Manufacture. Production of Airflow Bodies Demands Utmost in Welding Art, J. Geschelin. Automotive Industries (Aug. 11, 1934), vol. 71, no. 6, pp. 166–168. Variety of methods and equipment used in welding fabrication of Chrysler and DeSoto bodies; illustrated description of processes.

Automobile Body Manufacture. 160 Spot-Welds in 45 Seconds, J. Geschelin. Automotive Industries (July 28, 1934), vol. 71, no. 4, pp. 104–105.

Bridges, Steel. Strengthening Railway Bridges by Welding, O. Bondy. Ry. Engr. (Oct. 1934), vol. 55, no. 10, pp. 313–317. Examples of strengthened German railway bridges selected because of their novel structural features; advantages of welding; extent of strengthening; combined reconditioning and strengthening; welding *vs.* riveting; examples of reinforcement.

Chemical Equipment. Welding in Chemical Industries, C. O. Sandstrom. Chem. & Met. Eng. (July 1934), vol. 41, no. 7, pp. 360–364; (Sept.), no. 9, pp. 476–481. Weldability of metals; characteristics of various weld types; welding of pipe, pipe nipples and reinforcing rings, fired and unfired pressure vessels and flanges.

Electric Welding, Arc. Recent Developments in Atomic Arc Welding, J. A. Dorrat. Machy. (Lond.) (Sept. 27, 1934), vol. 44, no. 1146, pp. 768–769 and (Oct. 18), vol. 45, no. 1149, pp. 74–76. Operation of atomic welding set; welding technique; variation of solidification temperature range with carbon content.

Electric Welding, Arc. Fundamentals of Electric Arc Welding, B. Ronay. Am Soc. Naval Engrs. J. (Feb. 1934), vol. 46, no. 1, pp. 21–30. Notes on bare, coated and covered electrodes.

Electric Welding, Arc. Some Factors of Influence to Welded Part, M. Odada. Soc. Mech. Engrs. Japan J. (Oct. 1934), vol. 37, no. 210, pp. 705–710. Factors influencing properties of welding arc and deposited metal in arc welding from various types of welding rods were investigated; arc voltage of coated electrode was varied by coating material. (In Japanese with brief English abstract p. 93.)

Electric Welding Machines. Static and Dynamic Characteristics of Arc Welding Generators, A. G. Williamson. Metropolitan-Vickers Gaz. (Oct. 1934), vol. 15, no. 258, pp. 79–84.

Electric Welding, Resistance. Reducing Fabrication Costs by Spot-Welding, H. K. Liedy. Machy. (NY) (Sept. 1934), vol. 41, no. 1, pp. 33–34. Review of important principles and practices involved; characteristics of equipment used.

Gears and Gearing. Fabricated Steel Units for Gear Drives, W. C. Hawkins. Machy. (Lond.) (Aug. 30, 1934), vol. 44, no. 1142, pp. 648–649. Application of welding; points to be observed in production.

Industrial Plants. Arc-Welded Building at Messrs. Brown, Bayley's Works. Engineering (Oct. 19, 1934), vol. 138, no. 3588, pp. 406–409.

Metals. Hard Facing Lengthens Life of Equipment, G. Sykes. Eng. & Min. J. (Sept. 1934), vol. 135, no. 9, pp. 405–407.

Oxyacetylene Welding. Industrial Pipe Welding Practice. Chem. Age (July 28, 1934), vol. 31, no. 787, pp. 79–81.

Oxy-Gas Cutting. Flame Cutting of Steel for Welded Joints, E. J. Clarke. Mech. World (Oct. 12, 1934), vol. 96, no. 2493, pp. 337–339.

Shipbuilding. Some Examples of Arc Welded Ship Construction, D. Arnott. Soc. Naval Architects & Mar. Engrs.-Advance Paper no. 8, mtg. Nov. 15 and 16, 1934, 38 pp. Particulars and structural arrangements of some small all-welded ships recently built in United States, discussed from point of view of naval architect; early applications of arc welding. Bibliography.

Sugar Cane Mills. Welding on Sugar Plantation, R. B. Kay and R. A. Plaus. Facts About Sugar (Nov. 1934), vol. 29, no. 11, pp. 397–399.

Water Towers. Lowering Water Tank by Flame-Cutting Tower Leg, R. H. Patterson. Eng. News-Rec. (Oct. 18, 1934), vol. 113, no. 16, p. 502. Method of lowering 50,000-gal. tank at White Sulphur Springs, W. Va., from height of 60 to 40 ft., by gradually shortening legs of steel tower supporting it by means of gas-cutting torch.

Welding. Design and Manufacture of Welded Steel Fabrications, H. W. Hawkins. Mech World (Sept. 28, 1934), vol. 96, no. 2491, pp. 294–295; (Oct. 5), no. 2492, pp. 315–317.

(*Continued on page 34*)

WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

French Publication on Structural Steel Welding

In August 1933, the French Institute of Steel Construction, briefly known as O T U A, issued the first volume of a publication on Arc Welding which discussed the general characteristics of the process as applied to any field of industry.

During August 1934 the second volume of this work was issued. It is restricted to the Arc Welding of Structural Steel. It includes, however, about 50 pages of notes on Gas Cutting.

The publication appears to be a very clearly written, illustrated and printed compilation of recent practice in all countries.

Copies are obtainable from:

L'Office Technique pour l'Utilization de l'Acier,
25 Rue du General-Foy,
Paris, France.

New Pressure Regulator Booklet

The Air Reduction Company has recently published a new book, entitled "Pressure Regulators and Regulation Problems" which is of great interest to industry in general.

The booklet is printed in easily readable type, and is well interspersed with pertinent diagrams and charts which are so arranged as to permit the reader to quickly grasp the salient facts about pressure regulators and methods of solving regulation problems.

Design-Details Charts for Structural Engineers on Welded Connections

Loose-leaf design charts, letterhead size in blue-print form have been published by the Northern Bridge Company, 10 South La Salle Street, Chicago, Illinois. These illustrate several types of simple, yet effective, field tests by the hydraulic-jack method and give calculations of test data obtained on welded brackets supporting the new roof of the train shed at the La Salle Street Railroad Station in Chicago. Following this six charts are devoted to calculations and graphs for the design of beam to beam, girder or column connections and design of seat angles, eccentric weld connections and tables giving allowable weld stresses for design purposes. Length and size of welds required to replace rivets and a simple method to show welds on design and shop-details drawings are given on Chart 10.

Other charts will be added as further information is developed. These are being sent free of charge to those qualified to use them if requested on business stationery. To others a charge of 50 cents for the present set, which covers cost of publishing and mailing.

Major James S. Caldwell

Some of the charter members of the AMERICAN WELDING SOCIETY will be interested to know that Major James Caldwell visited the United States recently and participated in the discussion of the papers presented before the Society of Naval Architects and Marine Engineers held on November 15th and 16th. Major James Caldwell a well-known English authority on the application of electric welding to shipbuilding, was loaned by the British Admiralty during the war to assist the Welding Committee of the Emergency Fleet Corporation in its work in speeding up the applications of welding in ship construction. Major Caldwell is author of a large number of papers and reports bearing on all phases of the application of arc welding. In addition to being a member of the Society, he is also a member of the Institute of Civil Engineers and of the Electrical Engineers. He was Chairman of the Alloy Welding Processes, Ltd. until it became amalgamated with Murex, Ltd. in 1930. Since that time he has served as consulting engineer for the Quasi-Arc Company, Ltd. He was responsible for the early applications of electric-welded construction, including a cross channel barge in 1917–1918 and several factory buildings in 1919–1921.

Bound Volume Journal

The AMERICAN WELDING SOCIETY has made arrangements for members who wish to have their Journals for 1934 bound in attractive, imitation black leather covers to do so by sending copies of the twelve issues to Russell-Rutter Company, Thirty-third Street and Eighth Avenue, New York, N. Y., Att. Mr. Russell Lauben, Jr. A special reduced rate has been arranged at $1.75 per volume providing the issues of the Journal are sent to the binder on or before February 15th. The bill for the binding and return postage will be sent direct from the Society's office.

Correction

Mr. P. W. Fassler wishes to call attention to the omission in his article of the symbol ϕ; which article appears in the November issue of the Journal on "Projection Welding and Power Consumption." This symbol was omitted in connection with the power factor and in reference to the cosine of the angle between the voltage and current vectors.

Announcement Appointment 1935 Nomination Committee

In accordance with Art. VII, Sec. 1(*e*) of the By-Laws as recently amended, your President, with the approval of the Board of Directors, has appointed the following Committee on Nomination for elective offices falling vacant April 1935:

Chairman of Committee:

Mr. J. H. Deppeler
Metal and Thermit Corp.
120 Broadway, New York

Six Members of Committee:

Mr. F. M. Farmer
Electrical Testing Laboratories,
80th St. & East End Ave., New York

Mr. S. S. Scott
Brooklyn Navy Yard, New York

Mr. H. L. R. Whitney
M. W. Kellogg Company
225 Broadway, New York

Mr. E. R. Fish
Hartford Steam Boiler Insp. & Ins. Co., Hartford, Conn.

Mr. F. C. Fyke
Standard Oil Development Co.
Elizabeth, N. J.

Mr. H. E. Rockefeller
The Linde Air Products Co.
30 East 42nd St., New York

This announcement is made in order to afford you opportunity to offer suggestions for candidates for the various elective offices in time for consideration by the Nomination Committee. The Committee is required to render its report with written consent of nominees to the Secretary of the Society on or before the last Tuesday in January. The offices falling vacant are:

President (term one year)—Present incumbent: D. S. Jacobus (eligible for immediate re-election to this office)

Senior Vice-President (term one year)—Present incumbent: J. J. Crowe (not eligible for immediate re-election to this office)

Divisional Vice-Presidents (term two years)—Present incumbents: Pacific Coast—D. J. Williams (not eligible for immediate re-election). Southern—G. Raymond (not eligible for immediate re-election)

Five Directors-at-Large (term three years)—Present incumbents: C. A. Adams, H. M. Hobart and J. W. Owens (eligible for immediate re-election)

SECTION ACTIVITIES

BOSTON

On Friday evening, December 14th at 7:30 P.M., the Boston Section will meet in Room 403 of the Franklin Union, 41 Berkeley Street, Boston.

Mr. P. J. Horgan, of the General Electric Company, Lynn, will speak on "Welding," and Professor C. A. Adams of Harvard University and Director of the American Bureau of Welding will discuss the activities and purposes of this Bureau.

CHICAGO

A program of interest to all industries using welding, particularly the steel mills and refiners, was presented on November 30th in the Gymnasium of the South Chicago Y, M. C. A. The meeting was opened by Mr. Walter Mathesius, Asst. General Superintendent of the South Works of the Illinois Steel Company. An illustrated talk on heavy welding with particular reference to the welding of the Boulder Dam cylinder gates and nose liners was given by Mr. A. M. Candy of the Westinghouse Electric & Manufacturing Company. "Bill" Browning of the Linde Air Products Company spoke on machine flame cutting and oxyacetylene welding, and illustrated his talk with motion pictures.

CLEVELAND

The Cleveland Section held a very interesting meeting on Tuesday evening, November 14th, which was attended by a group of approximately ninety. The speaker for the evening was Mr. A. T. Douglass, Construction Engineer of The Detroit Edison Company, who spoke on "The Welding of High Pressure, High Temperature Steam Station Piping." The talk was illustrated by lantern slides. This was the first meeting of the season and the Section felt that it had a very good turnout.

The next meeting of this Section is scheduled for December 12th. Mr. J. W. Owens of The Pittsburgh Testing Laboratories will speak on the subject, "Weld Testing and Supervision." This talk will also be illustrated.

DETROIT

The December meeting of the Detroit Section was a joint meeting with the Society of Industrial Electrical Engineers and was held on the 5th. The speaker of the evening was Mr. J. F. Lincoln, President of the Lincoln Electric Company. Mr. Lincoln spoke on the fundamentals of arc welding as applied particularly to dies, jigs and fixtures, their fabrications, maintenance and alteration. He contrasted the American welding practice to that used in Europe, Japan and South America. His talk was fully illustrated by slides and moving pictures.

NEW YORK

A successful joint meeting of the local Sections of the AMERICAN WELDING SOCIETY and the American Society of Mechanical Engineers was held on November 19th. The opening address by Mr. Everett Chapman of Lukenweld, Inc., was a very instructive talk, using lantern slides, to show some of the difficulties and defects encountered in both welded construction and castings. Lively discussion followed.

The second paper by Mr. E. W. P. Smith of The Lincoln Electric Company was read by Mr. M. M. McGrew of the New York Office of this Company. It was a technical analysis of the design considerations that must be taken into account when replacing cast-iron machine members by welded steel members.

The third paper was presented by Mr. J. R. Baush of the Dodge Steel Company, instead of Mr. Longbottom of that Company, as scheduled on the program. Mr. Baush gave some interesting data on the use of steel castings in connection with welded structures and revealed some important data on the proper analysis for the best results in welding.

The next meeting of this section will be held on December 11th. The program includes a motion picture on the construction of the U.S.S. *Macon* and a paper by Professor Bradley Stoughton of Lehigh University, on "Flame Cutting of High-Carbon Steels." Lantern slides will be used to illustrate the lecture and the advisability of preheating and slow cooling will also be covered. Mr. W. D. Halsey of The Hartford Steam Boiler Inspection & Insurance Company will discuss the various sections of the A. S. M. E. Boiler and Pressure Vessel Codes, particularly with respect to welding. The talk will be illustrated with lantern slides showing a chart of "Welding Tours" through the A. S. M. E. Code.

The following are the dates and subjects for the first four meetings of the 1935 season:

January 14—Subject: "Welded Pressure Vessel Construction"
February 20—Subject: "Boulder Dam"
March 12—Subject: "Shipbuilding"
May 14—Subject: "Corrosion Resisting Steels"

PHILADELPHIA

Dr. D. S. Jacobus, Advisory Engineer of the Babcock & Wilcox Company and President of the AMERICAN WELDING SOCIETY, presented his address, "The Historical Developments of Fusion Welded Steam Boiler Drums and Pressure Vessels," at the November 19th meeting of the Philadelphia Section.

There will be no December meeting, but in January the Section will have a joint meeting with the Franklin Institute, which promises to be quite a big affair. There are to be demonstrations of the various kinds of welding with short talks on each. Notices containing further details will be sent out by the Section.

SAN FRANCISCO

The regular monthly meeting of the San Francisco Section was held at the Russ Building, San Francisco on November 16th, Chairman C. S. Smith, presiding. There are thirty-five members and guests present. Mr. Mathy, Chairman of the Program Committee promised a most interesting program for the next meeting to be held in Oakland.

Mr. Jack Morrissey, welding and fabricating expert for the Crucible Steel Company of America, gave a most interesting talk on "Welding and Fabricating of Stainless Steels." After his talk an open discussion was held. Following this Mr. Morrissey spoke briefly on some of his experiences in Russia as a welding engineer giving an insight into some of the difficulties he experienced there in trying to introduce modern welding methods.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A—166. Electric welder. Considered a first-class operator. Thirteen years' experience both at home and abroad, of which ten years have been spent as a foreman and instructor. Passed tests for Class II, A. S. M. E. Code for Unfired Pressure Vessels. Excellent references.

A—220. Welding operator. Have had training in oxyacetylene, welding, arc and atomic hydrogen, particularly the latter.

U. S. Civil Service Examinations

The United States Civil Service Commission has announced open competitive examinations as follows:

CHIEF ENGINEERING DRAFTSMAN
PRINCIPAL ENGINEERING DRAFTSMAN
SENIOR ENGINEERING DRAFTSMAN
ENGINEERING DRAFTSMAN
(For work on ships)

Applications for the positions of Chief Engineering Draftsman, Principal Engineering Draftsman, Senior Engineering Draftsman and Engineering Draftsman (for work on ships), must be on file with the U. S. Civil Service Commission, Washington, D. C., not later than January 14, 1935.

The entrance salary for Chief Engineering Draftsman is $2600 a year, for Principal Engineering Draftsman, $2300 a year, for Senior Engineering Draftsman, $2000 a year and for Engineering Draftsman, $1800 a year, subject to a deduction of not to exceed 5 per cent during the fiscal year ending June 30, 1935, as a measure of economy, and also to a deduction of 3½ per cent toward a retirement annuity.

Optional branches are (1) ship piping, (2) ship ventilation, (3) marine engines and boilers and (4) electrical (ship).

Certain specified education and experience are required.

Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post-office or customhouse in any city which has a post-office of the first or the second class, or from the United States Civil Service Commission, Washington, D. C.

(*Continued from page 31*)

Wire. Electric Welding of Wire, C. C. Downie. Machy. (Lond.) (July 5, 1934), vol. 44, no. 1134, p. 407. Short outline of methods, stressing importance of process; heat treatment.

BOOKS

Rules and Regulations for the Building and Classification of Steel Vessels. Chapter IX. Electric Arc Welding. Published by Bureau Veritas, 95 Broad Street, New York City. These regulations deal with the application of electric arc welding in this field.

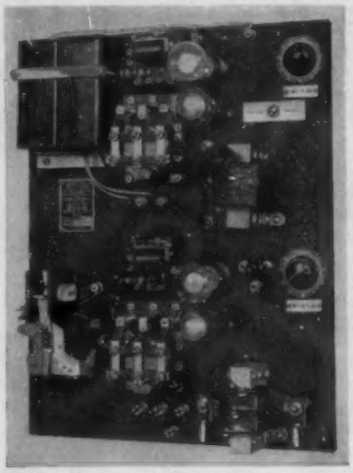
Specifications for Chrome-Manganese-Silicon Alloy Steel Boiler Plate. Prepared by Lukens Steel Company, Coatesville, Pa. Complimentary copies may be obtained.

(*Continued from page 22*)

necessity the same as in welding transformers. In regard to power factor, you have the choice by using high-resistance wire in the reactor of raising the power factor at the expense of the efficiency, the same as in motor generator sets, and they are no better. In motor generator sets, you can get 75% power factor and 50% efficiency, in transformers, 50%, power factor and 75% efficiency, which latter is better for the consumer and worse for the power company. If low power factor means better welding, let's have it. If any one desires to compare the same amperage and voltage alternating-current arc with its D.C. twin, they will find the temperature of the arc is much higher. This can be compared by Bausch optical pyrometer or by exposing photographic plates and noticing the difference in color or by exposing the inside of your wrist for two seconds to both a D.C. and an A.C. arc. From the difference in sunburn you will see which has the higher temperature or more ultra-violet ray action.

EC&M AUTOMATIC WELD TIMER

The AUTOMATIC-REPEAT Type *for Hydraulic and Air-operated Welding Machines*



THIS New EC&M Weld Timer for spot, butt and projection welders has two separate and distinct functions. One measures the heat units and the other function controls the opening and closing of the electrodes, giving a definite length of time after each weld to move the work along to the next welding position.

Both functions are independently adjustable, each having a separate dial as shown above. This permits selection of the proper setting for the application of power (Weld-Time) and the (Off-Time) period can be suited to the skill of the operator. A new operator can be started in with suitable "Off-Time" and this time can be gradually shortened up in small steps as he becomes more expert. Write for descriptive literature.

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150-28

GENERAL ELECTRIC

Mention "The Welding Journal"

TOBIN BRONZE...

used to fabricate 13,000-lb. hammer

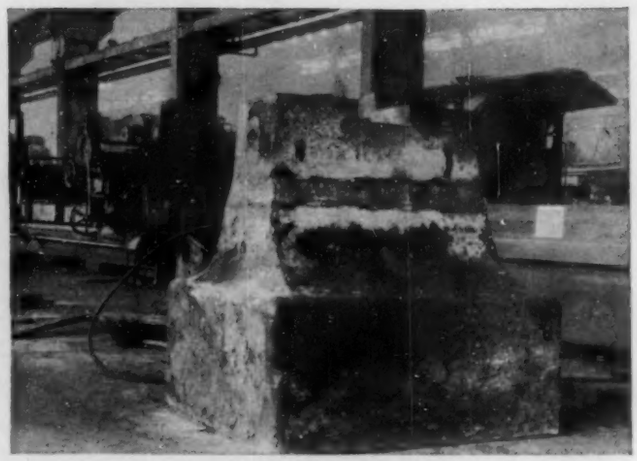
935 *lbs. of rod deposited in 14 hours*

HOW best to join the cast iron bottom and steel top of a 13,000-lb. steam anvil hammer? That was the question faced by a mid-western railroad shop... and solved by Tobin Bronze welding!

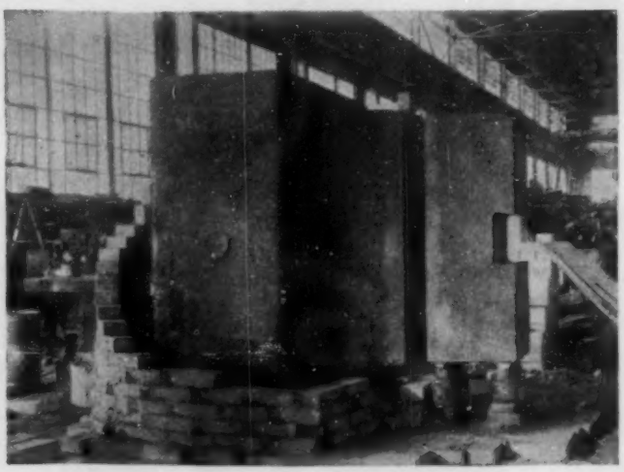
Because of the unusual nature of the job, a pre-heating furnace was built around the massive base . . . (in ordinary work the low melting point of Tobin Bronze usually makes pre-heating unnecessary). The weld was made vertically, to prevent the molten bronze from working ahead to insufficiently heated areas. Using two oxy-acetylene torches, it required but 14 hours to deposit 935 pounds of Tobin Bronze Rod and complete the weld.

Tobin Bronze was the choice for this particular job because of its uniformly high quality ... its "day in and day out" dependability. For the same reasons, thousands of experienced welders will use no other brand for the general oxy-acetylene welding of cast and malleable iron.

Anaconda Publication B-13, new edition, contains a wealth of practical bronze-welding information and describes the complete line of Anaconda Rods. Copies gladly mailed on request.



Ready for welding. Note the weld area between the steel top and the cast iron bottom.



The finished job . . . 13,000-lb. hammer fabricated with Tobin Bronze.

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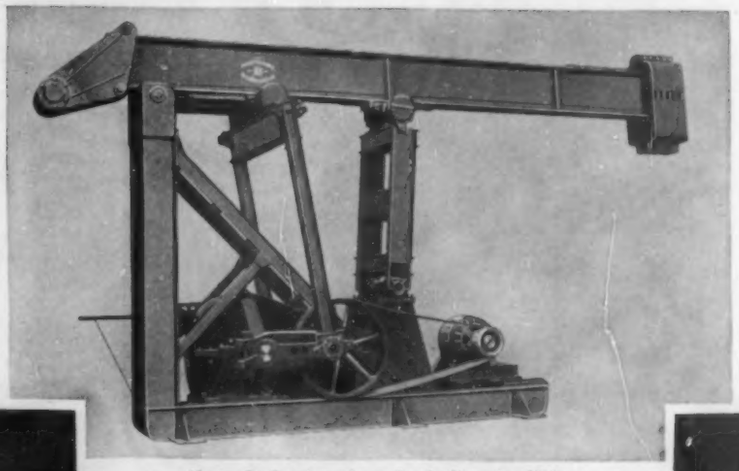
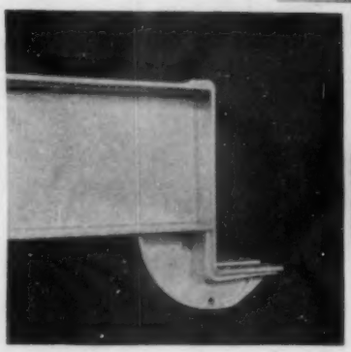


Above: Parkersburg Long Stroke Pumping Unit

Below: Parkersburg Walking Beam



Left: Nose of Walking Beam, showing Parkersburg welded construction.

Right: Base of Parkersburg Long Stroke Pumping Unit showing welded construction.

A new long-stroke pumping unit, designed to provide greater production with reduced power consumption, and to lower service and maintenance costs, is one of many oil field devices of welded construction made by the Parkersburg Rig & Reel Company.

The fabrication of such equipment is no ordinary welding job. It demands careful design and the best of workmanship. It calls for weld metal of high tensile strength and great ductility; requires continuously flawless welding. At the same time, welding costs must be kept reasonably low.

Seeking an electrode that would assure such results consistently, the Parkersburg Rig & Reel Company, after a series of comparative tests, has adopted Murex.

There is no doubt about it, Murex has set a new standard for electrode performance. In addition to providing weld metal of highest quality, these heavy all-mineral coated electrodes assure economical welding by being easier to use, by burning with a short, quiet arc that reduces spatter, and by depositing more weld metal per hour, as well as per pound of electrodes consumed. Write for the Murex booklet.

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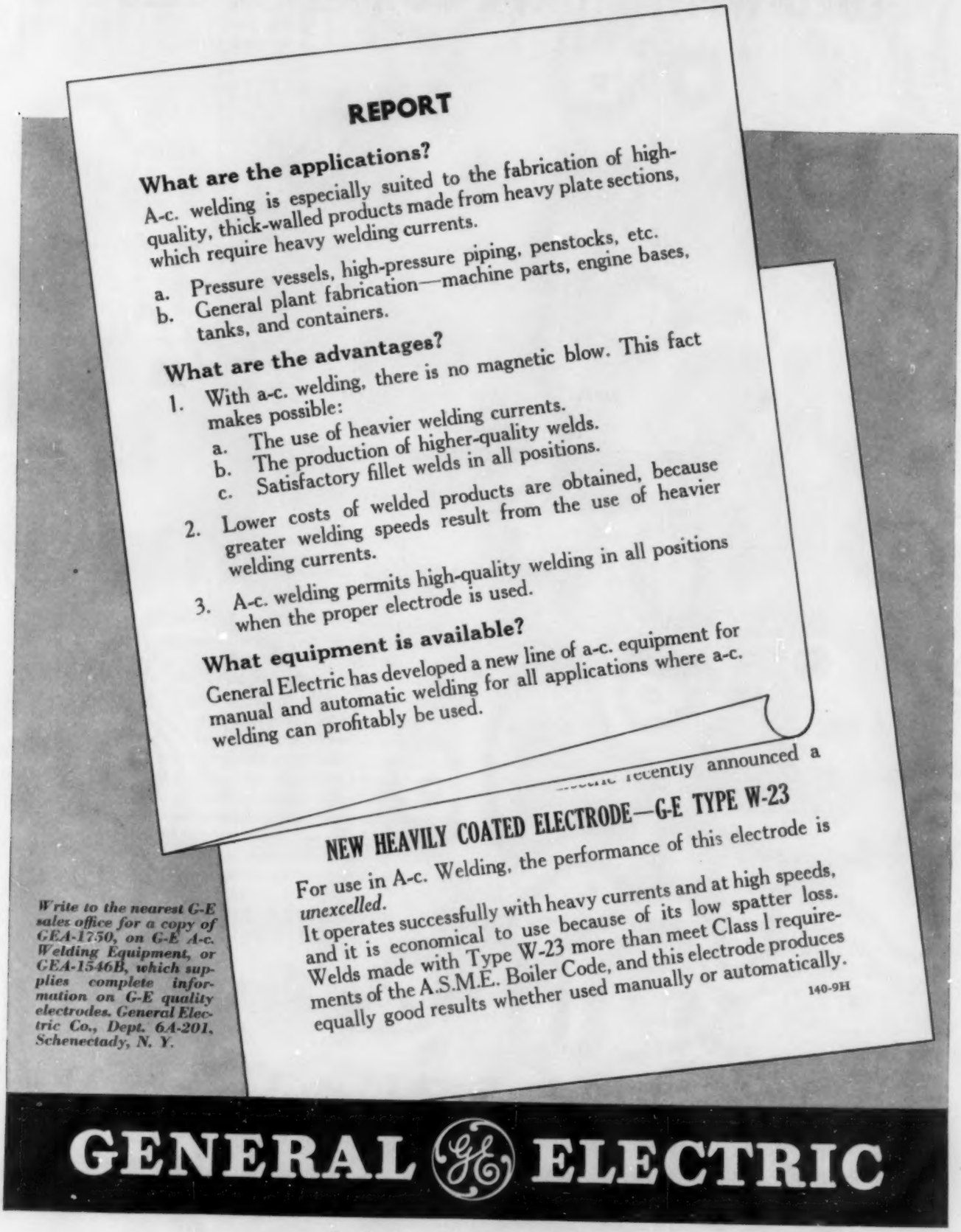
Mention "The Welding Journal"

A report on the findings of 15 years' investigation of Alternating-current Welding


REPORT
What are the applications?
A-c. welding is especially suited to the fabrication of high-quality, thick-walled products made from heavy plate sections, which require heavy welding currents.
a. Pressure vessels, high-pressure piping, penstocks, etc.
b. General plant fabrication—machine parts, engine bases, tanks, and containers.
What are the advantages?
1. With a-c. welding, there is no magnetic blow. This fact makes possible:
a. The use of heavier welding currents.
b. The production of higher-quality welds.
c. Satisfactory fillet welds in all positions.
2. Lower costs of welded products are obtained, because greater welding speeds result from the use of heavier welding currents.
3. A-c. welding permits high-quality welding in all positions when the proper electrode is used.
What equipment is available?
General Electric has developed a new line of a-c. equipment for manual and automatic welding for all applications where a-c. welding can profitably be used.
recently announced a
NEW HEAVILY COATED ELECTRODE—G-E TYPE W-23
For use in A-c. Welding, the performance of this electrode is unexcelled.
It operates successfully with heavy currents and at high speeds, and it is economical to use because of its low spatter loss. Welds made with Type W-23 more than meet Class I requirements of the A.S.M.E. Boiler Code, and this electrode produces equally good results whether used manually or automatically.
140-9H
Write to the nearest G-E sales office for a copy of GEA-1750, on G-E A-c. Welding Equipment, or GEA-1546B, which supplies complete information on G-E quality electrodes. General Electric Co., Dept. 6A-201, Schenectady, N. Y.
GENERAL ELECTRIC

NEW!
Just out...

MOST COMPLETE TREATISE On the Welding of STAINLESS-CLAD STEEL

More manufacturing companies have adopted or expect to adopt corrosion-resisting metals in their design than any other single improvement made or contemplated, according to a recent survey. The development of IngAclad Stainless-Clad Steel, because of its lower cost, greatly widens the possibilities for the use of Stainless Steel in all industries. Recognizing the desire of Welding Engineers to inform themselves on proper procedures in the fabricating and welding of IngAclad, the Ingersoll Steel & Disc Company offer this new book.

SENT POSTPAID on request to any member of The American Welding Society

Partial Contents of this Book

How IngAclad is made—where it may be used—where it should not be recommended—metallic arc welding—vertical welding—soldering—lock seam joints—riveting—drawing IngAclad—pickling and passivating—shearing, punching and drilling—cold forming and breaking—heat treatment and annealing.

Numerous photographs and line drawings are reproduced in this book to illustrate clearly the various procedures. Eighteen actual views of completed jobs give a fair idea of the many uses IngAclad has already found in many industries. By simply addressing a postcard or letter to this company, or by using the coupon below, you can obtain a free copy of "Manual of Welding and Fabricating Procedures for IngAclad Stainless-Clad Steel."

Write for your copy today

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Specialists in High Carbon, Alloy and High Speed Steel and Stainless-Clad Sheets
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Ohio Representatives: The E. W. Buschman Co., 626 Broadway, Cincinnati, O.
Missouri Representatives: Clark P. Schumacher, 3740 Washington Ave., St. Louis, Mo.

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Position.....

With.....
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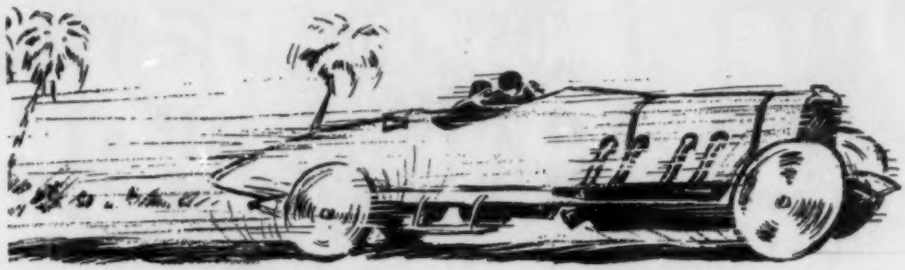
Mention "The Welding Journal"



100 ft. per hour with ALTERNARC

THE TREND IS TOWARD A. C.

Now and then we come across what is considered a natural combination. In simple form we mean such combinations as Bread and Butter—Paint and Brushes—Coat and Trousers, etc. In the art of welding we have Shielded Arc and A. C. Welding, a combination that presents the last word in welding practice.

United States Gov't. Using Shielded Arc and A. C. Welding at Boulder Dam

Left: Pipe for the hydraulic-power and flood-control tunnels at Boulder Dam is now being fabricated by The Babcock & Wilcox Company using shielded arc alternating current welding exclusively. This work includes the forming and welding of pipe 30 ft. in diameter . . . the largest ever constructed.

Lower: Nine of the forty-eight Babcock & Wilcox Boiler Drums with fusion-welded seams built for U. S. Scout Cruisers "New Orleans," "Astoria" and "Minneapolis" . . . the first naval vessels to be equipped with boilers having drums of this construction.

ELECTRIC ARC CUTTING & WELDING CO.

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Plus
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Plus
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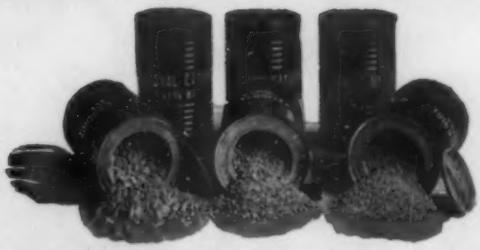

National Carbide Sales Corporation

Lincoln Building **New York**

4 NEW ADDITIONS TO A FAMOUS FAMILY

WELL known—most generally specified to assure perfect results—Premier Tested Welding Wire, both gas and electric, has established enviable records for better work at less cost. Uniform of structure—free flowing and deeply penetrating qualities—and its ease of identification are factors that have gained such widespread usage. And now—to this famous family—four new additions have been made. Additions that will be welcomed because they make available wires exactly adapted to specific welding problems.

1 •E. W. for electric welding is specially processed and recommended for certain conditions where a wire having a slightly faster melting rate would be advantageous.

2 •H. S. for gas welding is a rod specially processed for welding on steel having .20 to .40 carbon. It is free flowing, easy to handle and gives welds of high tensile strength and increased ductility.

3 •Nickel Steel for gas welding with the amount of nickel varying according to the demand. This rod is the basis for a strong weld. Used on gear teeth, auto bumpers, etc.

4 •U S S 18-8 Stainless and Heat Resisting Alloy Steel Welding Rods for both gas and electric welding in all commercial grades. Furnished bare in 36" lengths for gas welding and in 18" lengths, with a suitable coating for electric welding.

"U S S Chromium-Nickel Alloy Steels are produced under licenses of Chemical Foundation, Inc., New York; and of Fried. Krupp A. G., of Germany."

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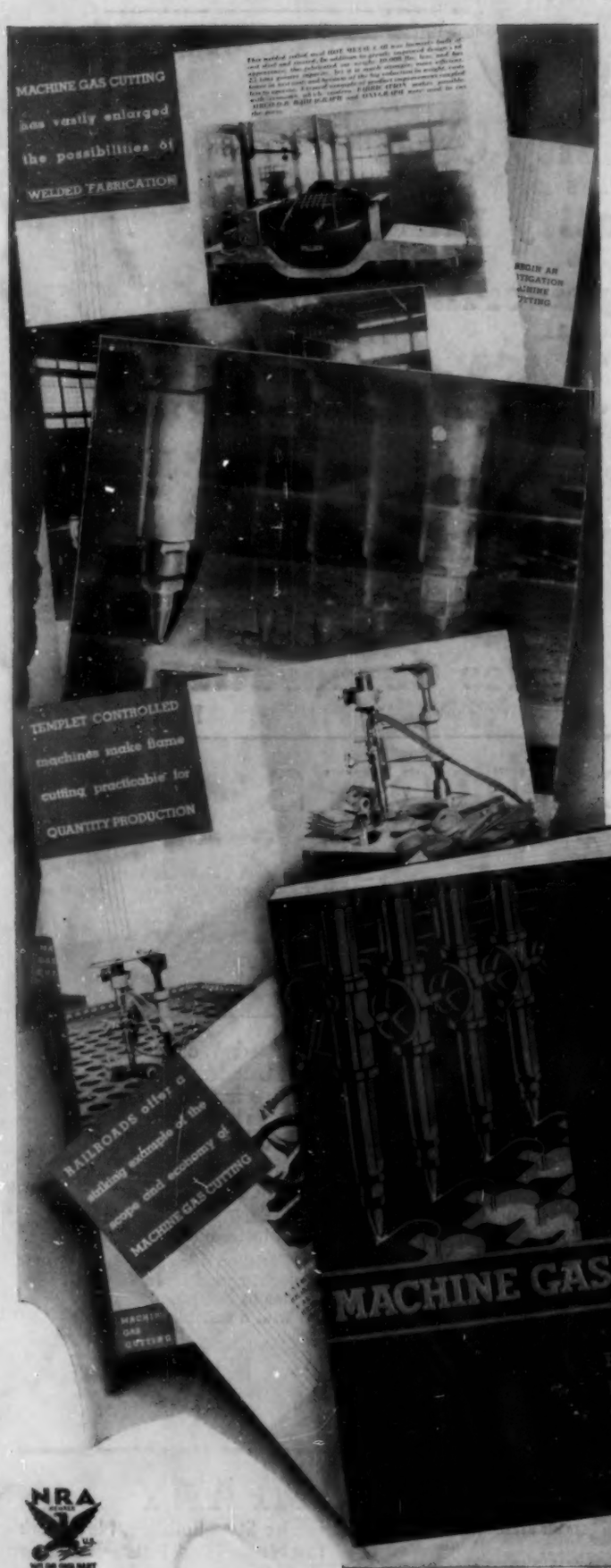
Put MACHINE GAS CUTTING on your 1935 COST CUTTING PROGRAM . . . .



In making plans for 1935, manufacturers of ferrous metal products should give careful consideration to MACHINE GAS CUTTING, a process laden with possibilities for improving design, speeding up production and effecting great economies in the making of steel parts of almost every description, and in the modern practice of welded fabrication.

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Production executives of metal working companies are invited to write for this 92-page book in which the story of MACHINE GAS CUTTING is fully told. Numerous examples from every-day usage, strikingly illustrate the possibilities of the process. AIRCO'S complete line of machines is illustrated and described. Your request on your business letterhead will bring you a copy.

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